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Impressions of Europe by an American Grassland Specialist[1]

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I RECENTLY returned from a 21 months tour of duty in Europe. During that time, I was with the European Office of the Food and Agricultural Division of our government's Foreign Operations Administration.

My headquarters was in Paris, but most of the time I was working in one or another of the various countries associated with us in our defense against Russian aggression.

My work took me into 14 countries, from Greece and Algeria on the East and South, to Scotland and Ireland on the North and West.

It was the aim of our government to aid the various European governments in improving their respective situations economically, socially and politically. My responsibilities were those of a pasture and forage production consultant. In all countries there was need for more and better animal products more economically produced, usually for local consumption but sometimes for export. Improvement in the production and utilization of pasture and forage was generally recognized as the most effective means of producing better animal products at lower cost.

My work in various countries was upon invitation from the ministry of agriculture of the respective country through our mission office in that country and our European office in Paris.

Everywhere I went I was warmly received, diligently worked, and cordially treated. The native people made me feel that they were glad to see me, that they appreciated the help, and that they were sorry to have me leave.

Upon my first visit to a country, I was hesitant to express my opinions freely since conditions were frequently very different from those in the United States. The right answer in America was not always the right answer for the situation at hand.

However, as time passed, I found myself in a more favorable position. Not only did I have my own American background, but, I had opportunity to see what was being done in the various European countries. I also had a chance to see what results were being obtained on the research and demonstration farms in the country where I happened to be working. I discovered that if I kept my eyes and ears open, I could frequently learn of and call attention to important facts, already known to some, but up to that time overlooked by most, which would improve the experiment, the demonstration, or the farm practice under study.

I discovered, too, that pasture and forage improvement leaders were eager to know what was being done in the other countries, including the United States, and what procedures and techniques were giving best results. In return for any help which I might give, I was continually trying to gather new facts and learn of new techniques which would be helpful to me and our American program later.

Four Phases of Work

The work within the various countries consisted generally of four phases. First, were fact-developing conferences with representatives of our local mission in the country and representatives of the government of the country being visited. Such conferences were for the purpose of orienting the consultant, and presenting the grassland problems and projects of the country.

The second phase was an on-the-spot study of research projects, farm demonstrations and extension programs in representative areas.

The third phase was a joint evaluation of projects and programs and a discussion of possible future projects and programs.

Before leaving a country the consultant prepared for the benefit of the country's project leaders, our local mission in the country, and the Paris office, a report giving the consultant's final evaluation of the situation and his suggestions for future action. These final reports usually resulted in requests for return visits of the consultant to help develop new phases, to review new or revised projects, or, to observe the effectiveness of new procedures and techniques. A few countries I visited only once; most I visited twice; and to a few, I returned a third time.

I left the job unfinished, but think much good was accomplished. I was only one of a group of consultants, each working in a different agricultural subject matter area. This consultant work is not an expensive feature of the Foreign Operations Administration program, but I think in many respects, it is one of the most valuable phases. It results in good will and progress and a minimum of friction.

Some General Impressions

From each country, I learned new lessons, but I wish to spend a little time here on general impressions.

I was kept too busy in my respective area of subject matter to go into detail of social and political matters, but one cannot associate with others for considerable periods without forming some general impressions. A few of these, I here list as follows:

(1) The main problems in Europe now are the same ones which caused World Wars I and II. The best way to prevent World War III is to solve these problems.

[1] Invitational paper presented before the general meeting, American Society of Agronomy, St. Paul, Minn., Nov. 8, 1954.

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(2) The militant aggressive Russian type of communism which is now causing so much trouble in the world is an outgrowth of these unsolved problems.

(3) Our military might has, doubtlessly to a very considerable degree stopped the flood of communist aggression, but it has not and cannot solve the problems which caused the wars.

(4) Our cooperative civilian activities are our most effective means of solving these deep-seated problems and preventing World War III.

(5) I do not know of a single communist among those with whom I associated, but considering the number in some of the countries in which I worked, I suspect that some with whom I was at one time or another associated may have been communists. It appears evident that many have become communists not because their intentions were evil, but, rather because their desires were good. In their despair they turn to communism in hope of finding help for the evils they see and feel. This is a new idea to many Americans, and at once raises the question as to what is the best means of changing their point of view. Is it to beat them down and keep them down, or, is it to demonstrate to them that there is a better way to attain their ideals? Even though some beating down may become necessary in emergencies brought on by communist aggression, it will probably be the demonstration of the superiority of democracy rather than the beating that will bring about a change in the loyalties of many who have been following communist leaders.

We may subdue a dog by beating, but something more is necessary before we can make him our friend. Many people the world over, it appears, have run wild with communism. It is necessary to stop them but not to unnecessarily abuse them.

(6) We seem to have made some progress in stopping communist aggression, but there is in the minds of many in Europe a serious question as to whether we have done so well in demonstrating the superiority of democracy.

(7) Many people in Europe feel that communism cannot be destroyed by defeat in battle, but only that communistic aggression can be militarily restrained while the demonstration of the superiority of true democracy is in progress. Such demonstration, they think, and that only, will result in the decline and death of communism.

(8) The countries with the strongest and most active cooperatives are the countries with the highest average standards of living and in which communism has made the least progress.

(9) Communism is most prevalent in those countries where there exists the greatest difference between the wealthy and the poor, where class discrimination is most pronounced, and where those with the ability to climb have been denied the opportunity to climb.

(10) The European people with whom I worked in all the countries in which I worked sincerely appreciated our cooperation and aid. However, they resented being told that they should. They feel that the common good is more important than who gets the credit. They are inclined to doubt the sincerity of people who are overly zealous about full credit. They feel that they, not we, are on the front line and that they must suffer most in the event of another war.

We shall now return to the matters more specifically agricultural and observe in detail some of the things from which we might take lessons in that area.

Greece

We shall begin with Greece, for there we have had farming operations in progress for many thousands of years. The relative decline of Greece from the era of her glory may be ascribed to many wars and various other causes, but certainly, one of the major factors is in the destruction of agricultural land. In Greece, we have an illustration of the result of population outgrowing agricultural knowledge and the development of sound soil conservation and production practices. At this date, one wonders what should be done. Some have said that obviously goats have been a big factor in the destruction of the soil and therefore goats should be disposed of. This overlooks the fact that on such land, only the goat can live and only by the goat, can the people live. There is no place else for the people to go.

The shepherds who live with their flocks and in winter dwell in very humble homes, ask little and can afford to be independent. Change is necessarily slow. Many things are as they are because for as long as man knows, they have been that way. A change which does not prove to be for the better, is likely to be fatal. One must, therefore, be very cautious in the changes one advocates.

Erosion has left almost no soil on the rocky slopes in many parts of Greece. In other areas where wheat once grew, gullies have destroyed the land. The proper corrective measure would appear to be to get more of the land in grass, protect from over-grazing and retire rough uplands to forests. But this again leaves us with the question as to what to do with the people in the meanwhile.

In the last analysis, it becomes obvious that by some means the productive power of the land must be increased. There must be much greater production per acre. Little fertilizer has ever been used, especially on pasture and hay crops. Neither can it be used under present social and economic conditions. There are considerable areas of level permanent pasture land in the low lands which could be irrigated, and seeded to alfalfa. Other areas can be drained and put into grain and hay crops. The production of extensive areas of permanent pasture can be doubled or quadrupled by phosphate treatment and grazing control. This calls for changes in land use and in the methods of handling livestock and for a new economic structure. It calls for very careful research to determine or develop suitable crop varieties and production methods. It calls for grazing control experiments. Finally, and probably, most of all, it calls for an intensive agricultural extension program. To all of these, our Foreign Operations Administration has given encouragement.

Land use and soil conservation practices in the high lands of Northern Greece include planting of trees, and the development of grasses and legumes. The most abundant of the latter were meadow and tall fescue; but also found, were timothy, bromegrass, orchard grass, Kentucky bluegrass, white and red clover and other trifoliums. Greece has more than 70 species of clover.

We are giving encouragement to their fine work now in progress in alfalfa. The unfortunate fact is that too many centuries passed before the need for such research and educational work was recognized, and in many instances the damage is now beyond repair.

I should like to direct your attention to the American Farm School of Salonika which is doing some of the finest work I have ever seen in the training of Greek boys for agricultural leaders. If any in my audience would like to

make a financial contribution to a very worthy cause, I recommend to you the American Farm School of Salonika. They carried a number of demonstrations in cooperation with the Greek government in which we were interested.

Italy

In Italy one meets a wide range of conditions. In some areas in Southern Italy and Sicily, the rough, steep eroded land and the dense population present a rather hopeless situation. However, in other areas, as in the Po Valley, we find some of the best farming and highest production per acre in the world. This valley presents many good illustrations of intensive land use and excellent soil conservation.

The Jemma Brothers north of Naples have reclaimed a swamp area and are doing intensive grassland farming in which their grass production is utilized by water buffalo for cheese making. Many such projects are now in operation. The Italian experiment stations are doing excellent work with little money and little help. Much work is being done in forage crop breeding with various legumes and grasses. There is a new leafy variety of orchardgrass. We should have some of this in the United States.

One problem in most of Europe, not recognized generally in America, is the necessity of providing employment. The land owner in many sections must hire or support people in proportion to his acreage. He may use modern methods and let half the workers watch the other half, or, he may use old methods and let all work. For example, in seeding wheat, five persons are often engaged where one would do the job in the United States; but there is probably nothing else for them to do. As a result of limited work and surplus time, art in some sections is highly developed, as illustrated by the painting on houses in the Alpine villages of Northern Italy.

There too we find good and intensive farming. Water pipe lines for irrigation have their intake in streams high up. The natural pressure is adequate to give good distribution from nozzles to field further down. Irrigation of meadows is a common practice in the Alps.

Hay and pasture are the most valued crops. They provide nearly all the livestock feed, and in the more densely populated areas, all forage is harvested by hand and carried to the barn for feeding. This generally gives the highest production of animal products per acre. Many in America are debating whether to harvest and barn-feed or to graze. It would seem that where land is the limiting factor, harvesting and barn feeding might be justified; but where labor is a limiting factor, grazing would be preferable.

In the farming of the Po Valley, we find a combination of hard work, good cultural practices, liberal fertilization, irrigation, and conservation and use of all organic waste, including city sewage. All leaves, weeds, straw and the like, are built into compost piles. Under this intensive farming system, grass is still found to be one of the most profitable crops.

Meadows may have as many as nine hay crops removed in a single year. Grass and Ladino clover is cut when it is 4 or 5 weeks old and has a very high protein content. Consequently protein supplements are not fed in the barn. Wet hay is being produced and used successfully at one Italian experiment station farm. The moisture is 35 to 40 percent. In the home area of Ladino clover, a system of irrigation, fertilization, and clipping produces Ladino at its best. In fact, Ladino clover seems to have been a natural development resulting from the system of meadow management.

Austria and Germany

In a pasture improvement demonstration high in the Alps of Austria, excellent grass extends up the slope so far as fertilizer is used. Beyond that, weeds and brush have taken over. There are many demonstrations of this type in Europe and America but farmers generally are too prone to substitute plowing or renovation for good fertilization and good management. Plowing or other soil working and reseeding without adequate fertilization is a process of further soil depletion.

Hay and pasture are the main cow feeds in Europe. The importance of good hay is more appreciated there than in the United States and much work is devoted to hay-making.

Near Grins in the Austrian Alps, the high production level of the land is a feature of interest, for this land has been farmed for centuries with animal manure as the only fertilizer. Grass is the main crop. On one Austrian farm in the Alps, 10 cows on 10 acres produced 80,000 pounds of milk per year with 1,700 pounds of concentrates as the only purchased feed. All land was in pasture and hay. All income came from the farm.

In Germany, as in Austria, liquid manure is an important item of productivity. Basic slag is the most commonly used form of phosphate on pasture land in Germany. It is generally applied by hand in early Spring as the snow leaves the fields.

France, Luxembourg, and Belgium

In a typical grassland community of Eastern France about 85% of the land is in grass, of which probably 80% is permanent sod. Young grass hay provides the protein for winter feeding. Much hay is carried to the barn on a special rack strapped on a man's back. Happiness there is not a matter of wealth, but, rather, in being a fitting part of the community.

In pasture experiments with irrigation and fertilization at Nancy, France, the cost of irrigation was half of the gross returns for the extra milk produced.

In Luxembourg, the farmers live well but are not rich. There is no communist problem here. Wages are higher than in France. The neat manure pile is a common sight here and great care is used in the preservation of manure. The trench silo is also the common one in Europe. The blower is the common means of putting hay in the barn in Luxembourg. Meadows generally are chiefly grass meadows, but some alfalfa and clover are grown.

A Luxembourg farm garden is a profusion of flowers and beauty. Possibly we should have more of this in our modern farm gardens. From the farmer of Luxembourg, I think, we might learn that the pleasures of farming are not all in the income.

In Belgium, it is common to see four pasture paddocks with a common watering trough. The Belgian farmer thinks that excellent pastures are the most profitable use for this land, even though it is level and excellent grain land. In a pasture of ryegrass, bluegrass, meadow fescue, and white clover pasture, we noted an excellent growth even in August. Nitrogen is intensively used on meadows and pastures on the most productive and profitable farms of Europe.

The British Isles

In England we saw a 7-year-old alfalfa field on the Cave Brothers' farm near London. These brothers use 1,000 pounds of muriate of potash per acre when seeding alfalfa, and

lighter annual applications later. Phosphate is also used. The Cave Brothers may use too much potash, but it raises a question as to whether the average American farmer uses enough on alfalfa.

It was interesting to observe the work of ground moles on a farm near Hereford, England. How much soil below the surface is placed on top each year by insects, ants, earth worms, rodents, etc.? This amount is probably far in excess of that generally thought of. It may be a big factor in accounting for the excellent response frequently obtained from surface applications of fertilizer on permanent grassland and long leys.

From the Scots, we can learn much in care, patience, and determination. These traits are evident even in the neatly constructed oat stacks on Scottish farms. Rationed rotational grazing in Scotland is giving pleasing results. Pasture experiments at the West of Scotland College of Agriculture include grazing mixtures. The production of the meadow or pasture depends not only on the productivity of the soil, but, also, the botanical composition of the crop.

Experiment Station grounds in Europe are well kept. Some of ours are too, but, generally American research workers are not as particular as the European in the care of his plots.

In Wales, meadows and untreated hard fescue pasture are the main crops on some upland farms. Some research and extension workers advocate plowing of such pastures and reseeding as the only good method of improving. However, farmers of Wales prefer to quit farming rather than go to that expense. The land is steep and frequently rough. A premium of $28.00 per acre is now paid for plowing such pastures in England.

The hard fescue in untreated pastures is refused by the sheep which hunt for the few scattered plants of other species. Consequently, the production per acre of animal products is very low.

Some research workers at the nearby Experiment Station decided to try some surface treatment of lime and phosphate. As a result, the fescue gave way to a volunteer development of ryegrass, bluegrass, and white clover. Where the plots were not fenced, the sheep soon found them, and the treated plots were eaten almost to the surface of the soil.

Ireland is a natural grassland country. It has large areas of permanent pasture, some of which have been down for centuries, and are among the most productive in the world. However, others are badly depleted and are badly in need of fertilization and reseeding. I was particularly impressed by one of the most beautiful pastures I have ever seen in the southwestern part of the island. It had been liberally fertilized, and reestablished with ryegrass, meadow fescue, and white clover. It carried 2 animals per acre for nearly 10 months per year. The shock came, however, when the farmer showed us another "weedy" pasture which was producing as much or possibly a little more. These two adjoining pastures had like treatment and management. The farmer had seeded the "weedy" mixture. His question and mine is this: do our livestock need more variety in our pasture herbage?

Netherlands

In the Netherlands, it is obvious that the Dutch take excellent care of their cows as one can see blanketed cows on pasture in early Spring. They also take care of their pastures, and produce more milk per acre than any other country in the world. We visited a Dutch farm of 50 acres with 45 milk cows and 65 animal units. From the Dutch we can learn much in the care of pastures and in the care of cows.

Carbohydrates must be fed to cows on pasture to dilute the high protein content of the pasture in the Netherlands. Farmers use a feed box on wheels which contains the by-product from a potato starch factory.

Even in the Netherlands, with its many canals, it is sometimes necessary to provide water for cows on pasture. A simple method used is a tank wagon with drinking cups as the cows move to a new paddock or area each day.

At the soil and plant testing laboratory at Oosterbeek, soils are tested to determine advisable fertilizer treatment and forages are tested to determine feeding practices. We might give this idea more consideration in the United States.

In closing, I should like to mention a visit to an American Cemetery in Belgium. Should I remind you that we have too many American soldiers buried in Europe? Carelessness and indifference to the welfare of others in time of peace, lead onto to another war. Now is the time for Americans to study, and, if possible, to solve international problems justly. The world is watching America. If we conduct ourselves as worthy members of a true Democratic State, the threat of another World War may be removed.

Hybrid Corn Development in Europe and Mediterranean Countries[1]

R. W. Jugenheimer[2]

HYBRID corn, a product of North American agriculture, has emigrated to all parts of the world. Directed against hunger and poverty, hybrid corn has started a peaceful, constructive revolution in Europe and Mediterranean countries.

International Agencies Cooperate

The present national hybrid corn programs in Europe and the Mediterranean countries are supplemented in various ways through the activities of the Food and Agriculture Organization of the United Nations (FAO), Foreign Operations Administration of the United States (FOA), and the Organization for European Economic Cooperation (OEEC). Time does not permit giving the names of many persons who contributed to this program. Some references to the program are listed at the end of this report.

FOA and OEEC have provided technical assistance in the breeding and production of corn. They have sponsored the importation of seed for commercial plantings, and of seed for European production of hybrid seed. These organizations have also sponsored two surveys of the work on hybrid corn. The aims and objectives of FOA have been presented on this program by Mr. J. Walker.

The primary function of FAO is to promote international cooperation in the fields of food and agriculture. FAO has a membership of 71 nations. Appropriately, its motto is "Fiat panis" which means, "Let there be bread".

Headquarters of FAO are in the center of historic old Rome. The staff totals over 1,000 employees at headquarters and 350 experts throughout the world. Cost of the entire FAO program to the United States is about one cent per person per year. Technical divisions of work include agriculture, economics, fisheries, forestry, and nutrition.

FAO guides and stimulates cooperation of corn workers in 25 European and Mediterranean countries. The program involves testing American hybrids, and conducting scientific research to develop inbred lines and hybrids especially adapted to widely differing conditions.

The hybrids in test represented a maturity range from 70 days to 155 days. Locations of the nearly 200 tests ranged from Apelsvoll, Norway, at a latitude of 60° 42′ North, to Sids, Egypt, at 28° 54′ North, and from Western Portugal to Eastern Turkey.

On the basis of data from the various experiment stations, reports were prepared of regional performance tests, plant density experiments, cultural trials, and fertilizer studies conducted in 1950, 1951, and 1952. Printed copies of these reports, summarizing the work in the various countries, are available from FAO, at Rome, Italy.

Technical papers are presented by many of the workers at annual meetings. Regional committees each year evaluate current cooperative research, and plan a more complete program for the next season. "Minimum Seed Certification Standards for Maize" have been developed. These standards should safeguard the interests of farmers and facilitate international trade of hybrid seed.

Benefits of Hybrids

Yugoslavia, Italy, Egypt, and Turkey grow large acreages of corn. Nearly 18 million acres of corn are grown in 17 countries in Europe and the Mediterranean region. This area produces nearly 500 million bushels of corn. This production, however, might be doubled by the use of adapted hybrids and modern production practices.

Hybrid corn is rapidly replacing open-pollinated varieties in many countries (see table 1). Early maturing hybrids have made possible the growing of corn in many new areas of Belgium, the Netherlands, and France. Nearly all of this new corn acreage is planted to hybrids. In France and Belgium, hybrid corn is replacing some of the excessive beet and potato acreage. In Switzerland, corn can supplement grass for feeding, and aid in eliminating black foot disease of wheat. Adapted corn hybrids are giving promise of rapidly replacing low-yielding varieties in many other countries.

Earlier maturity, higher yields, better standability, and greater resistance to insects, diseases, and drought are the characteristics of certain American hybrids that have helped boost the acreage and production of corn in Europe and the Mediterranean area. A recent survey by the FAO indicates that the use of hybrid corn in 10 countries in 1952 increased production by nearly 11 million bushels.

Use of hybrids almost doubled from 1952 to 1953 (see table 1). About 6% of the nearly 18 million acres in corn in 17 countries was planted with hybrid seed in 1953. In that year, the increased production from the use of hybrids was nearly 20 million bushels. Potential increase from the use of hybrids in these countries is at least 160 million bushels.

The 5-year testing program sponsored by the FAO was started with an original investment of only $40,000. The value of the estimated increased corn production in 14 countries was worth over 24 million dollars in 1952 and nearly 40 million dollars in 1953. Italy and France received especially large dividends from their hybrid corn programs. The value of the potential increase from the use of hybrids in the 14-country area is 320 million dollars per year.

It was found that the best of 45 American hybrids provided by FAO produced 60% more grain than the best local open-pollinated variety as an average of 141 tests in 13 countries in 1952. If the 30 million acres of land in corn in the area were planted to the best available hybrids, the resulting increase in yield would be equivalent to the production of an additional 18 million acres of good land.

Many People are Hungry

Many Americans are concerned over the apparent surplus of agricultural products accumulating in the United States. They feel that increasing the food supply in other areas of the world will compete unfavorably with American farmers. It is difficult for these Americans to realize that over half of the people in the world are hungry.

[1] Invitational paper presented before the general meeting, American Society of Agronomy, St. Paul, Minn., Nov. 8, 1954.

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Table 1.—Progress in hybrid corn production in Europe and Mediterranean countries, 1952–1953. (Report of the Seventh FAO Hybrid Maize Meeting, February, 1954)

Country	Corn area in hybrids		Estimated increased corn production from the use of hybrids			
	Percent		Bushels		Value in U. S. dollars	
	1952	1953	1952	1953	1952	1953
Algeria	8.8	32.5	*	78,750	*	142,860
Austria	*	5.0	*	94,500	*	168,000
Belgium	99.0	99.0	78,750	78,750	160,000	140,000
Egypt	0.13	0.02	23,625	335	53,000	5,600
France	15.0	28.0	590,625	4,528,125	1,300,000	11,714,300
Greece	10.0	10.0	393,750	393,750	1,000,000	1,000,000
Israel	*	16.0	*	354,375	*	1,350,000
Italy	8.7	15.5	8,662,500	11,812,500	20,000,000	21,600,000
Morocco	1.72	0.8	27,917	109,699	60,000	200,000
Netherlands	75.0	80.0	196,875	157,500	500,000	290,000
Portugal	0.90	0.9	376,149	403,397	750,000	777,206
Spain	3.56	12.3	393,750	1,181,250	600,000	2,250,000
Switzerland	4.0	9.0	2,362	5,119	7,500	12,260
Yugoslavia	*	1.0	*	94,500	*	112,000
Total			10,746,303	19,292,550	24,430,500	39,762,226

* Figures not available.

Practically all of the better crop land of the world is now being farmed. Some acreage can be added by costly conservation, irrigation, and reclamation projects. However, increased food and feed production must come primarily from the land now being farmed. This vital area of land is now feeding a population of 2.4 billion persons. In addition, world population is increasing at the rate of approximately 48 babies born every minute of every day for a total of 25 million a year.

Use of adapted American hybrids and modern production practices are gifts from the United States and Canada which may aid in eventually doubling the production of corn in many sections of the world. International cooperation is a two-way street. Corn and tobacco are native to America. However, many other important crops, types and breeds of livestock, and valuable processes and products like pasteurization, DDT, and penicillin were gifts to the United States from foreign countries.

Seed Production and Processing

Much of the seed for the FAO testing program, which began in 1947, was contributed by the American and Canadian seed trade, and by various state and federal agencies in the United States. At the present time, however, most of the hybrid seed used in Europe is produced in European countries.

Total domestic production of hybrid seed in 14 foreign countries increased from approximately 345,000 bushels in 1952 to 662,000 bushels in 1953 (see table 2). More than half of this seed was produced in the fertile Po River Valley of Italy. Spain and France also produce considerable hybrid seed corn.

Enough hybrid seed could be available to plant all of the European corn acreage in a few years. The actual change from open-pollinated corn to hybrids, however, will depend largely on the superiority of the hybrids, availability of seed, effectiveness of the extension programs, and freedom from governmental control. Assuming arbitrary rates of planting and yields, it should be possible to start with 48 acres of inbred lines in 1954 and have plenty of double cross hybrid

Table 2.—Total domestic production of hybrid seed corn in bushels.

(Seventh FAO Hybrid Maize Meeting, 1954)

14 Countries	1952	1953
Algeria	0	394
Austria		10,238
Belgium	1,181	79
Egypt	394	22,050
France	66,938	67,922
Greece	5,119	9,844
Israel		2,362
Italy	196,875	393,750
Morocco	197	0
Netherlands	21,262	23,625
Portugal	8,308	7,284
Spain	44,100	95,288
Switzerland	315	669
Yugoslavia		28,350
Total	344,689	661,855

Table 3.—Estimated acreages and yields necessary to produce hybrid seed corn to plant 25 million acres (includes seed and pollen parents).

Year	Kind of field	Acres needed*	Estimated yields, bushels	
			Per acre	Total
1954	Inbred lines	48	10	480
1955	Singles crosses	2,880	8	23,040
1956	Double cross seed	138,240	30	4,147,200
1957	Hybrid production (Farmer fields)	24,883,200	40	995,328,000

* Estimated on the basis that a bushel will plant 6 acres, that seed will be grown on selected, desirable fields, and that yields of farmers' fields will average 40 bushels an acre.

seed to plant 25 million acres of farm fields in 1957 (table 3). Purchasing some of the inbred and single cross seed in the United States should materially hasten the procedure.

Production Practices of Farmers

Modern production practices must go hand-in-hand with the use of desirable hybrids. Food for plants is just as necessary as food for humans and animals. Genes for high yield in desirable hybrids can reach their fullest expression only when the plant is grown on soils well supplied with sufficient amounts of balanced plant food.

Number of plants per acre must be adjusted to the water supply and productivity of the soil. Spacing and population studies have been conducted in many countries. Smaller, earlier-maturing hybrids need to be spaced more closely to get optimum yields than larger, later maturing hybrids. Farmers need to use more efficient methods of cultivation, harvesting, and storage if hybrids are to give best results. Expansion and development of irrigation projects are needed in many dry areas.

The experience and facilities of American seedsmen can be utilized in many other parts of the world. In Italy, thousands of bushels of hybrid seed are sold in bags with three well-known United States trade marks. Similar opportunities appear to be available in Turkey, Yugoslavia, Egypt and other large corn growing areas. Some sub-standard and unadapted seed has been exported from the United States. This is unfortunate and must be stopped if American seedsmen are to keep their excellent reputations for selling only seed of the highest quality.

Hybrid corn revolutionized American agriculture. It promises to be an increasingly important crop in many other sections of the world. This includes areas where little or no corn is now being raised. Hungry people are not happy people. In hybrids we have high hopes of providing much needed food and feed.

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Aims and Objectives of the Food and Agricultural Program of the U. S. Foreign Operations Administration[1]

Joe E. Walker[2]

BEFORE he left Washington to attend regional meetings of FOA Agricultural Officers in Europe and the Near and Far East, L. H. Norton asked me to extend to you his deep appreciation for your invitation to take part in this program. He also asked that I extend to all of you his most sincere regret at being unable to attend. He was truly disappointed the last day he was in Washington when he asked me to take his place.

Mr. Norton's misfortune has been my very good fortune. I am very pleased to be able to attend a Society meeting again after having missed the last seven while I have been out of the country.

The subject I am to discuss with you is the "Aims and Objectives of the Food and Agricultural Program of the United States Foreign Operations Administration." Before discussing these aims with you, I would like to digress for a moment and mention some of the points that have affected the situation in which our country now finds itself. Most of these points all of you already know, but I believe that what I have to say will be more clearly understood if you keep them in mind as I talk.

It is an historical fact that after the dissolution of the Roman Empire civilization passed through a period of stagnation insofar as progress in science, culture and world trade were concerned. This is the period that our history books call the Dark Ages. Now what caused this disastrous stoppage in progress? One explanation, and a very good one, is that no country in the world was prepared to take the leadership in the family of nations. This condition continued until there were nations strong enough to gain and maintain world leadership. At about the time our country won its independence, the great colonial empires of the leading nations of the world began slowly to break up. During our lives this process has been accelerated. We are now living in another age when there is rivalry for world leadership. The accelerating increases in world population has further complicated the situation. I venture to say that there is no one here today who has not read within recent months some report on the dangers of over-population in the world—and that at some future date there would not be enough food to go around. We must and will be prepared to produce more food as population increases.

[1] Invitational paper presented before the general meeting, American Society of Agronomy, St. Paul, Minn., Nov. 8, 1954.

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The United States is no longer apart from the rest of the world. Whether we like it or not, our traditional isolation from the rest of the world has been a thing of the past for two generations. In this age, most nations are dependent on other nations for various commodities that they want or need in order to exist. No country is completely self-sufficient. We find ourselves dependent on other countries for certain minerals and plant products that we do not have or cannot produce. At one time or another all of us have heard the phrase "stockpiling strategic materials". At the same time, other countries are dependent upon us. As agronomists we here are very much interested in what other countries buy. We wonder, can our exporters find a market for the 40% of our wheat, 30% of our cotton, 10% of our fruit, 35% of our rice, 17% of our tobacco, and for the other crops of which we produce more than we can consume here at home. This interdependence of nations plus improvement in communication and transportation have caused international relationships to become even more closely interlocked in recent years.

These changes I have mentioned affect our *economic* lives. In other parts of the world new and sometimes dangerous *political* philosophies are causing other changes. One of these has been adopted by a strong nation which is convinced that its mission is to impose its dogma on the rest of the world. To protect themselves, the peoples of the free nations are cooperating in building a bulwark of security against this threat. Or to put it another way, most of the nations of the world are on one side or the other of two factions which are struggling for leadership. Our country is working with her sister countries who have similar ideals and beliefs in developing leadership in the free world. We have accepted the leadership in many international activities, one of which is improving and increasing agricultural production in 55 cooperating countries.

And what do we have to offer? In the agricultural field I would say that we have demonstrated our ability to produce agricultural commodities, and other countries want to learn how to do it for themselves. But before we get to bragging about ourselves too much, I want to point out that we did not develop this crop-producing ability overnight. One hundred years ago it took about five people on a farm to produce enough to feed themselves and one other person. Fifty years ago, three people could produce enough for themselves and for two others. Now, one farmer produces enough for himself and six more people in the United States, plus some more left over to export.

This great increase in productivity per farmer has not taken place in most countries. How would you say we have done this? I can tell you how I think we did it. I believe we did it because we learned how to make science work for us. Many of the basic scientific laws or facts which we used to develop hybrid corn, the reaper, the combine, the cotton picker, improved seeds of all kinds, the use of fertilizers, the use of plant and animal by-products and so on—the complete list would be very long—were discovered in other countries. But you people, your predecessors and other men working in other fields of science and mechanics have taken scientific facts and helped the American farmer to apply them. And there we find one of our objectives in our work with the agricultural people of the Free World. We want to fill in anything missing in their reservoir of scientific knowledge and then help them to put it to use for their own good.

As I said a moment ago, we did not learn how to use scientific knowledge in a day. Our nation was about 90 years old before we set up our Land Grant College System. It was 17 more years before we provided for research on experiment stations in connection with these colleges. And it was another 25 or 30 years before we arranged for the systematic spreading of knowledge gained at these colleges and experiment stations to the people who could use it—the American farmer and his family. Therefore, we who administer this operation in those countries where farming is still a hand operation, cannot expect our ideas to be accepted without question, because they are often ideas which at first may appear unreasonable to them.

For the past 2 or 3 years, U. S. specialists who have cooperated in the training of foreign technicians brought to the United States have urged greater emphasis in training in the regions from which the trainees come and we are moving rapidly in that direction. In other words, train them there at home. It is cheaper in time, money and man power. At this time, 21 such training projects in Europe are being finished; a regional work-shop on Agricultural Extension methods will be held in Manila soon, and I'm sure some of you attended the water spreading conference to which foreign technicians were invited. It was held in our Western States October through December 1953. There have been others, the rice fertilizer and breeding working parties held in Tokyo last month, for example. It is at such meetings that international exchange of information is fostered just as you and I are discussing our work here in St. Paul this week.

Now I would like to lay before you some of the problems our people face in the so-called underdeveloped countries of the world. Our objectives are to help in their solution. I cannot give them to you in their order of importance because they are so inter-related that they cannot be separated. They are:

1. *Poor production, poor distribution or both.*—Not enough food and fiber is produced where they are needed or where they can be processed. And for one or another reason, food and fiber that are produced are not properly distributed.

2. *Low health standards.*—It is difficult for an American who hasn't been in the less developed countries to appreciate what this means. In the last country where I was assigned, and it is by no means the least developed, it is far ahead of most, in fact, there were whole communities 100% infected was malaria, other communities over 90% infected with schistosomiasis; and malnutrition was widespread. This malnutrition was not due to lack of food but to an unbalanced diet. A majority of the people there have never eaten a balanced diet and many of them don't like the taste of the foods necessary to make up a proper one.

3. *Idleness.*—I mean idleness on the farm as well as in the cities. Many, many farmers work only 100 days a year. A most fertile breeding place for Communism is among idle men who are living in poverty watching their hungry, naked children die from lack of food and medical care.

4. *Lack of credit, both domestic and international.*—It makes no difference how good a farmer is or what the natural resources of a nation may be—if they don't have the wherewithal to make a start they get nowhere. Many of us are old enough to remember the plight of the American farmer when he lost his credit during the late 1920's and early 1930's. We know what it is not to be able to gain enough financial momentum to keep going.

5. *Poor distribution of farm population.*—In the country I mentioned a moment ago, and again I want to emphasize that it doesn't represent conditions at their worst—the average family farm is about 5 acres. Some of the farms are as small as 125 square yards. Can you imagine a whole family living off the produce of 125 square yards of land? At the same time, that country has thousands of acres of cut-over and burned-over land that can be farmed profitably.

6. *Lack of knowledge.*—I know of one country, and I am sure there are others, in which only two citizens are graduates of a college of agriculture equivalent to our own; and one of these men is not in public service. It is a monumental task there to organize an extension service, for example, when none of the home agents and few of the county agents have the equivalent of high school education.

7. *The need for practical research and its application.*—For example, there is a top-notch technician in the Near East who worked on an insect called the *dacus fly*. He found out all about its life history, how it fed, what it ate, how it lived and all the other things an entomologist finds when he studies a bug. He wrote up his findings in a well prepared article and delivered a magnificent speech on what he had learned to an Academy of Science. He delivered his manuscript to the academy editor for publication and then he returned home happily looking for other insects in good supply that he could study. He left his *dacus* friends to continue destroying from 10 to 40% of the olive crop of his own and neighboring countries. Now I may have exaggerated this story a little bit but you see what I mean.

Of course, by now you people know what our aims and objectives are. I could say there really is only one objective. That is we want to work alongside people of the free countries of the world to help them develop their agricultural production and distributiton to a stage where populations will be adequately fed and employed and not be a breeding ground for Communism or other fanatical "isms". We want to help people in their own efforts to provide themselves with medical care, food, clothing, education, tools, land, purchasing power, and the other things that will enable them to improve their living standards.

The 1954 Mutual Security Act or Public Law 665 provides for a two-pronged approach to the agricultural problems of the underdeveloped countries. One is the extension of technical aid and the other is for "development assistance". A statement of the purpose of the Act is, as follows:

"It is the policy of the United States . . . to aid the efforts of the people of economically underdeveloped areas to develop their resources and improve their working and living conditions by encouraging the exchange of technical knowledge and skills and the flow of investment capital to countries which provide conditions under which such technical assistance and capital can effectively and constructively contribute to raising standards of living, creating new suorces of wealth, increasing productivity and expanding purchasing power."

This act authorizes the expenditure of *up to* a total of \$88,570,000 in the Near East, Africa, South Asia, and Far East and Pacific nations, and *up to* an additional \$28,500,000 for Latin America. All of this money is for technical assistance. An additional authorization of up to \$199,000,000 was made available for development assistance. With nearly all sections of Western Europe fully recovered from postwar economic despair, emphasis of the mutual security programs has shifted from this area to the Near and Far East.

When the United States agrees to join other countries in a programming of technical cooperation, the host country agrees, first, to bear a fair share of the costs; second, to integrate the programs and to make good use of their results; and third, cooperate with other countries in technical programs.

In planning these joint programs, increased emphasis has been placed on 2- to 3-year university and other contracts. As of Nov. 1, fifty United States educational institutions had contracts with FOA for work in 27 foreign countries. Oklahoma A and M College, working in Ethiopia was one of the first. Their work began in 1952. They now have about 34 staff members out there. No doubt many of you have gone or will go to some country under one of these contracts. We have 71 Land Grant Institutions in the United States. That is more than one for each of the countries where we have agreements for technical cooperation. Can we assist in setting up a central experiment station which will carry on after these contracts have expired? That certainly is a challenge to all of us. Under these contracts, members of the college staff are assigned to the cooperating country usually to work with a corresponding host country school or experiment station or both where they guide and help in the development and operation of research projects in a manner similar to the way we are accustomed to doing it here. Except overseas, we do not try to do all or even most of the actual work. We encourage our counterparts on the local staff to direct *their* work into more efficient and productive channels. We actually do the work only when we demonstrate how to do a job.

In all of the cooperating countries there are FOA Missions. They are called United States Operations Missions, or USOM's. These Missions are staffed with technicians as deemed necessary to operate the technical program that has been mutually agreed upon. The Mission technicians work with counterparts in the national government; agronomists work with their counterparts who are usually in the Department of Agriculture. They are charged with the responsibility of helping their counterparts use available resources and whenever possible better techniques; to give training to other technicians; and to help in the organization of permanent government agencies which will contribute significantly to the economic development of the country. They are concerned with such projects as seed improvement, distribution and exchange; extension methods and vocational education; use and distribution of fertilizers; resettlement; soil conservation; forest maintenance and restoration; fisheries; livestock improvement; land use; range management; water use and conservation; irrigation; pest and disease control and others as are needed. Technicians assigned to the Missions are constantly at the shoulder of their counterparts: questioning, encouraging and advising in their work—and in many cases, learning themselves.

Another extremely important part of the technical assistance program is the training that foreign technicians receive in this country. I am sure all of you are familiar with this FOA activity. Most of you have worked with these people. About 60 of them are or will be in attendance at these meetings this week. In working with these people we have a two-fold objective. They should be, and they are, receiving the opportunity to advance in their field of work. Also they are contributing largely to our own fund of knowledge. Equally important with this training is the impressions and ideas they gain about us an individuals, how we live, our churches, our schools, in other words, the American way of

life. The experiences that these people take home is having and will continue to have a very marked effect on what they and their countrymen are going to think of us now and in the future.

Now I want to mention two other of our most important objectives. These two objectives are to a much lesser extent involved in direct contact with foreign nationals. At least we practice them right here at home. The first of them is the coordination of the available manpower and brainpower in all the diverse agricultural activities of the United States into this operation. We need, as a nation, a concentrated effort for the expansion of productivity and purchasing power and improving working and living conditions of the people in the world's underdeveloped areas. Some of you may have heard that the Farm Bureau Federation, in cooperation with foreign countries and FOA, is arranging for 600 young farmers between the ages of 18 and 30 to come to the United States where they will live and work on farms selected by the Farm Bureau—another example of cooperative effort. I have already mentioned the trainee program in which most of you either directly or indirectly are cooperating. The Department of Agriculture and State Experiment Stations are a reservoir upon which we draw continuously for trained men, information and support in our planning and operation. And then there is FAO, the Food and Agriculture Organization of the United Nations. Our operations are planned to dovetail with those of FAO. For example, at the University of the Philippines, College of Agriculture in Los Banos, FAO has sent a forest products specialist who is supervising the construction of a forest products laboratory, the installation of the equipment, and the training of the College of Agriculture personnel in its operation. After consultation with private industry relative to the best equipment, FOA bought the equipment and the University of the Philippines and the Philippine Government are paying for the buildings and installations, and staffing the laboratory. Cornell University has a contract with this college. Therefore, at this one institution, we have FAO, FOA, a Land Grant College, American Industry, and a University in another nation working together for one common goal. There are other examples of this kind of united effort, and there will be more.

The second important objective we can accomplish here at home is for us who have put in tours of service abroad to maintain contacts made overseas with the people with whom we have cooperated. Mutual help need not end with the termination of a tour of duty at a foreign post. And it would be a healthy thing for world peace if agency-to-agency and people-to-people contacts were continued after termination of contracts and agreements.

Now one last idea—in his talk to all of our technicians who go to the field, E. N. Holmgreen, Director of the Office of Food and Agriculture of FOA gives them what he calls his "five points for failure in the field"; to them I have added a sixth. These potential danger points are:

1. *Too many Americans on the job.*—There is an absorption rate at which a college, experiment station, high school or department of agriculture can take technical guidance. If they are overloaded with new ideas, their efforts lose direction and the institution is soon bogged down and progress stops.

2. *Getting Americans on the job too fast.*—Occasionally we are able to recruit and deliver a technician to a country before it has local funds available, or before arrangements have been made for interpreters, ahead of the equipment he is to work with or even before the local government has a counterpart ready for him. A technician arriving under one of these conditions will be hunting a job to do, and it creates a very bad impression.

3. *Spreading the technicians too thin.*—This is a constant problem. It is present in all the Missions.

4. *The technician trying to do all the work himself.*—Operation is the job of the local counterpart. If you do his work for him—and I grant this is often easier than teaching—he won't learn as much and the American technician has less time to spend with other counterparts. Then when you leave, the host country technician isn't able to carry on.

5. *Planning above the ability of the country to pay.*—It is all too easy to start more programs than the country can or will wish to pay for after the Americans are gone. And any time or money spent starting a project that cannot be completed, and carried on by the country concerned, obviously is wasted.

6. *Not recognizing foreign technicians as equals.*—All of you know you can't successfully teach a class here by talking down to the pupils or talking over their heads. We must always remember that a foreign technician generally knows more about his home conditions than we do. And most of them are authoritatively informed in their fields.

In the words of the President ". . . These programs are our most effective counter-measure to Soviet propaganda and the best method by which to create the political and social stability essential to lasting peace." Possibly I should add that it is the cheapest counter-measure in dollars and blood that we can employ.

I would like to thank, in behalf of the Office of Food and Agriculture, all of you agronomists for helping us with our program. Thanks to you who have gone abroad and taken part in it. Thanks to you who have come back home and continued to send information and encouragement to the new friends you made at your posts. And thanks to you who will go to take their places and carry on the work.

The Wet Milling Properties of Grain Sorghums[1]

S. A. Watson and Yoshiro Hirata

FOR over 40 years grain sorghum has been mentioned as a possible raw material for commercial starch production (3, 4, 5, 9, 10). Reasons given were similarity to corn in composition, kernel structure, starch properties and ease of starch isolation. Corn Products Refining Co. became convinced of the merit of this claim and in June, 1949, completed a wet processing plant at Corpus Christi, Tex. (7). Products manufactured include starch, crystalline dextrose, oil, and feeds. This company also has an affiliated plant at Regensburg, Germany, where similar products are made from grain sorghum imported from the United States.

It can now be said with some degree of confidence that starch can be made commercially from grain sorghum. In light of the experience of the past 4 years, the ways in which grain sorghum is *not* similar to corn with regard to wet milling properties can be discussed. In a process having a flow of approximately a million pounds of milled grain a day, small and seemingly minute differences in kernel characteristics may create serious bottlenecks in the production stream, which may impair product quality. The importance of certain structural features of the grain sorghum kernel were not entirely appreciated until manufacturing was actually underway. Many unanticipated problems arose during the first 2 years of operation but close coordination between production, research and engineering departments provided the solution or answers to most of these problems. These investigations have revealed new information on grain sorghum that may be useful in guiding the plant breeder in his search for improved varieties and may stimulate further industrial utilization of this potentially much more important crop.

METHODS

Description of manufacturing process.—Grain is received by truck or rail, cleaned, dried to 12 to 13% moisture if it is to be stored for a long period; or it may be sent directly to the steeps. In the steeps it is covered with process water containing sulfur dioxide and subjected to a softening and leaching action which lasts for 50 to 60 hours at a temperature of 120 to 125° F. Two batteries of 10 steeps each are operated so as to maintain a pH level of 4.0 to 4.2 and a concentration of about 6% soluble materials in the steepwater withdrawn from the battery. Water is passed over the grain by continuously pumping it from the bottom of one steep to the top of the next steep. Water movement across the battery is in countercurrent relation to the age of the grain. The low pH is the result of formation of lactic acid through fermentation of sugars extracted from the grain. Following the completion of steeping, the wet grain is crushed just enough to release the germ without damaging it. Since the steeped germ contains about 50 to 60% oil, it is therefore readily separated from other kernel components by flotation on the suspended starch. Oil is removed from the dried germ by expelling under pressure. The remaining pericarp and endosperm mixture is finely ground to release the starch granules.

The fiber fraction, which includes pericarp, aleurone and a few small pieces of endosperm that escaped crushing in the mill, is separated from the starch and protein fraction (gluten) by screening over very fine bolting cloth approximating 200 mesh. Starch and gluten are next separated by the use of continuous centrifugal machines. The light gluten fraction passes from the centrifuge at 60 to 65% protein and is sent to the feed house where it may be dried separately or mixed with fiber, steepwater, and germ oil cake and dried. The mixture is sold as milo gluten feed. The starch, after further purification by passing through a second centrifuge, is washed with fresh water and either dried or sent to the sugar refinery for hydrolysis to yield dextrose. Finished starch purity is primarily measured by the residual protein content which must be below 0.5% in an acceptable product.

Laboratory steeping.—All samples of grain processed in the laboratory are steeped in a solution composed of 0.5% lactic acid and 0.15% sulfur dioxide adjusted initially to pH 3.0 with potassium hydroxide. Three hundred fifty grams of grain (dry basis) is covered with 1500 ml. of the steeping medium in a 2-quart Mason jar and immersed in a water bath held at 120 to 122° F. The liquid is circulated with a pump 10 minutes every hour for a total of 48 hours. Under these conditions the pH of the medium rises rapidly toward pH 4 levelling off at pH 4.2 to 4.3.

Laboratory milling.—Quantitative laboratory fractionation of steeped grain is accomplished by the procedure described previously (14). The four main components of the grain—germ, fiber, starch and gluten—are separated by means similar to those used in the manufacturing process except that starch and gluten are separated on a table. All fractions are dried in a forced draft oven at 130° F., weighed and analyzed. Yield determination is calculated on the basis of the raw grain dry substance.

Steeping solubles.—A 100 g. (d.b.) portion of grain is steeped in 400 ml. of the steeping medium and under the same conditions as described above. The entire sample of grain and its steepwater are ground 5 minutes in a Waring Blendor operated at full speed. The resulting grist is filtered and soluble dry substance determined by drying and weighing an aliquot of the filtrate. Correction is made for the reagents contained in the original steeping medium. Reducing sugars is determined on this extract by the Schoorl copper reduction method (2).

Starch color.—This is done by visually comparing under north light one or more starches and white magnesium oxide pressed between two glass plates on a black background. If the samples are placed on the lower glass in such a way that when pressed by the upper glass the edges of the samples come together, small differences in hue or intensity can be readily distinguished. Starches are arranged in order of relative intensity by cross comparisons. Numbers assigned are relative only within this group.

Chemical methods.—Starch is determined by a modification of the A.O.A.C. polarimetric method (1), fat by extraction with carbon tetrachloride in Butt extractors and protein and ash by A.O.A.C. Official Methods (1). Wax is extracted from whole kernels with Skellysolve B (11). Tannin is determined by the Menaul prodcedure (12) and a ground sample of grain.

DISCUSSION

Structural features of the grain sorghum kernel. The bulk of commercial wet milling experience in starch production has been with corn. Therefore, it is interesting to compare some of the similarities and differences between corn and grain sorghum. Probably the most obvious differences are in shape and size. The spherical nature of the grain sorghum kernel gives it different swelling characteristics during steeping than the irregularly shaped corn kernels. The small size of the grain sorghum kernel allows water to be absorbed more quickly and soluble substances to be extracted more rapidly and more completely than with corn. In grain sorghum there is a much greater proportion of horny endosperm than in corn. In the horny endosperm, cells are small, starch granules are small, and the gluten matrix is thick and resistant to softening. As a consequence, slightly longer steeping time is to be required for grain sorghum than for corn.

[1] Contribution of the George M. Moffett Research Laboratories, Corn Products Refining Co., Argo, Ill. Presented at the 1953 meeting of the American Society of Agronomy, Dallas, Tex. Rec. for publication April 8, 1954.

In figure 1 the major structural features of the grain sorghum kernel are shown. The effect of steeping on this kernel is evidenced by the loss of starch from the central floury endosperm region during preparation of the section. In milling, the readily loosened starch granules in this region are liberated during the degermination grind; but the starch granules in the horny endosperm are held more firmly and must be liberated by fine grinding in an attrition mill. Starch from both regions is combined after fiber removal. Figure 2 shows the manner in which starch granules are bound in the endosperm. Protein matrix forms a continuous envelope around all starch granules within a given cell. The function of steeping is to soften the protein matrix so that the crushing action of the mills will effectively release starch granules.

A previously unrecognized difference between the endosperm of corn and sorghum is the presence of a layer of small, densely proteinaceous endosperm cells in the sorghum kernel that lie just under the aleurone layer. This layer has been termed dense peripheral endosperm and will be described in detail in a subsequent publication. During milling, peripheral endosperm cells tend to be broken out intact and many are small enough to pass through the commonly used screens into the starch-gluten fraction. To produce a satisfactory starch it has been necessary to use special techniques and equipment not required in corn starch manufacture.

Composition.—Grain sorghum has in general a chemical make-up similar to corn, but the sorghum grown in the coastal bend area of Texas contains more protein and less fat than Midwestern corn (table 1). These analyses are averaged from daily grain samples collected over a 3½ year period and represent about 53 million bushels of corn and

Table 1.—Comparative composition of corn and grain sorghum.

Component, % d.b.	Yellow dent corn*	Grain sorghum†
Starch	72.1	71.1
Protein (N × 6.25)	9.5	12.8
Total fat	4.6	3.7
Total ash	1.4	1.5
Tannin	none	0.01
Wax	0.03	0.3-0.5
Xanthophyll and carotenoid pigments	5-70 μg/g‡	none

* Average analyses of corn received at Pekin, Ill., plant over 3½ years.
† Average analyses of grain sorghum received at Corpus Christi over the same period.
‡ Reference (4).

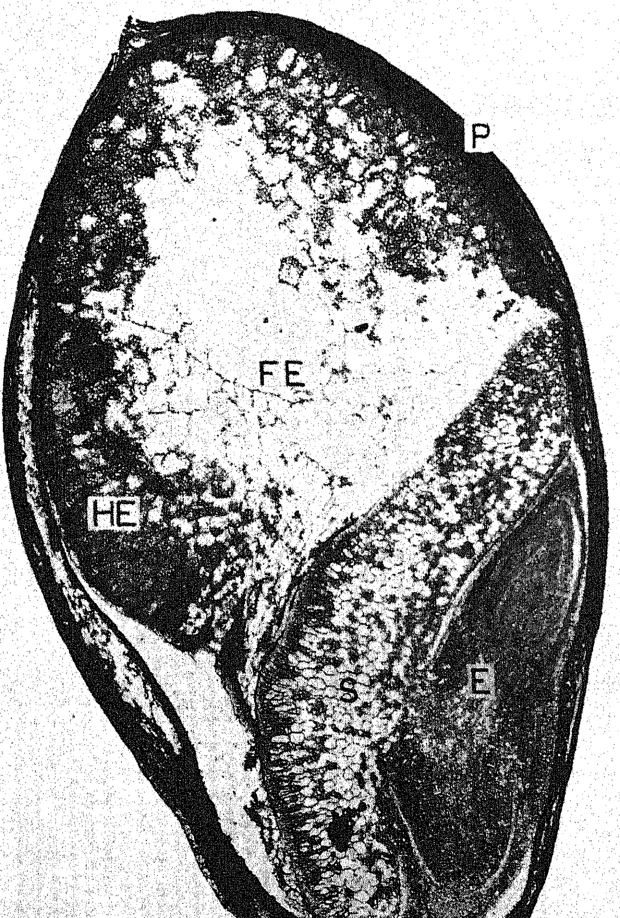

FIG. 1.—Longitudinal cross-section of steeped grain sorghum kernel. Thickness, 40μ; magnification, 43×. P, pericarp; HE, horny endosperm; FE, floury endosperm remnent; S, scutellum, and E, embryo which together make up the germ.

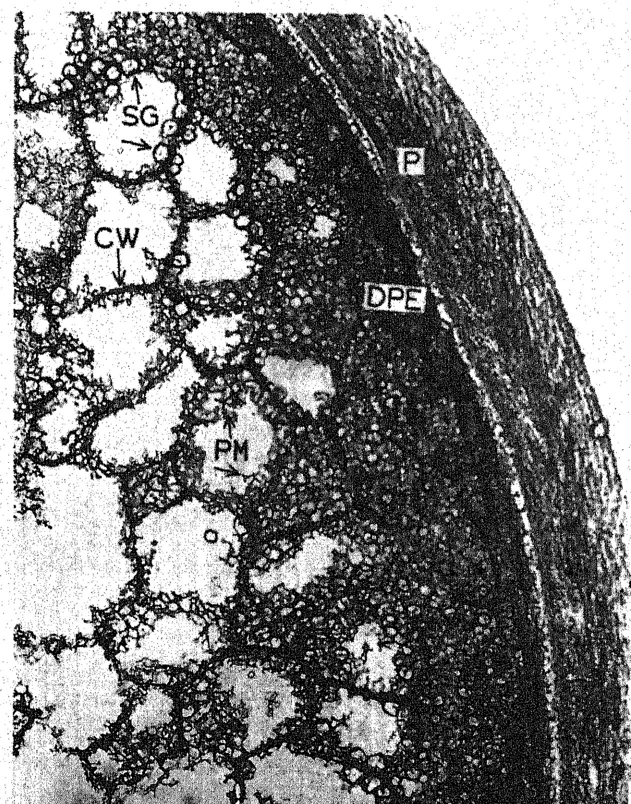

FIG. 2.—Cross-section of endosperm and pericarp of Martin grain sorghum kernel. Thickness, 25μ; magnification, 280×. P, pericarp; DPE, dense peripheral endosperm; PM, protein matrix from which starch granules have been removed; SG, starch granules still embedded in protein matrix; CW, cell wall.

18 million bushels of grain sorghum. Analyzable starch content in sorghum is not greatly different from that in corn but recoverable starch is somewhat lower because a greater proportion is contained in the horny endosperm. The oil content of sorghum is low but can probably be increased through plant breeding techniques. Grain sorghum of higher oil content would not only give the farmer a better balanced feed, but would give the processor a higher yield of oil, his most valuable by-product.

With respect to tannin, wax and yellow pigments, corn and grain sorghum differ distinctively. The discovery by O. J. Webster, Nebraska Experiment Station, of a grain sorghum variety having yellow endosperm is of considerable importance. Carotenoid and xanthopyll pigments in the endosperm are important to poultry rations and their absence in sorghum feeds results in lower acceptability. The presence of tannin in grain sorghum may lower its palatability as a feed, and its presence in the finished starch may result in formation of grey or blue colors in the presence of soluble iron. White grain sorghum varieties containing less tannin should be preferred. The large amount of wax in grain sorghum causes some trouble in oil recovery and must at least be discounted from the figure for total fat. However, this wax does have distinctive properties which may eventually win for it a place in the by-product field (3, 11).

Wet milling comparison of varieties, commercial experiences.—Martin grain sorghum is the predominant variety available to the Corpus Christi plant. However, Hegari, Plainsman, Caprock and Redbine 66 have occasionally been processed. Redbine 66 gave results comparable to Martin. Plainsman and Caprock, purchased in West Texas, appeared to be softer seeded types than Martin and gave starch of lower protein content, but also of lower viscosity. Hegari was one variety that was expected to be excellent for wet milling because it has a rather large, soft kernel with white pericarp. However, its pigmented seed coat (undercoat) proved to be so brittle that brown specks carried over into the finished starch and gave it an unacceptable appearance. For this reason alone Hegari, or any other variety with a pigmented seed coat, is not considered to be suitable for wet milling application. The starch now being manufactured from Martin variety has an almost imperceptible pink tint and is suitable for most industrial and food uses. Since this color may be due mostly to the adsorption onto the starch granules of pigment leached from the pericarp during steeping, varieties having white pericarp should be preferred.

Laboratory wet milling results.—None of the varieties having white pericarp and unpigmented seed coat have as yet been processed in commercial quantities. However, most of the important or promising varieties of waxy and non-waxy grain sorghums have been wet milled in the laboratory under methods closely simulating manufacturing conditions. Results are given in table 2 in the form of ranges and averages rather than values for individual varieties. Since only one or two samples of each variety were processed, it was felt that results were not completely representative of a particular variety and they were tabulated only on the basis of the broad classification as waxy and non-waxy. The numerous samples of Martin variety which have been processed have indicated that the same variety grown in different years and in different locations can show considerable variation in wet milling properties. The most significant differences occur between the group of varieties containing regular starch (non-waxy) and the group containing waxy starch. These two types of starch differ significantly in pasting characteristics and hence may have different end uses (3, 8). Waxy grain sorghum has not been wet milled commercially in significant quantities. No differences in gross composition

Table 2.—Average recovery and composition of wet milling fractions of waxy and regular grain sorghum varieties.

	Regular varieties*		Waxy varieties†	
	Range	Average	Range	Average
Raw grain analysis, % d.b.				
Protein	10.1 -14.4	12.5	10.9 -13.9	11.8
Starch	67.8 -71.3	69.3	67.8 -69.9	68.8
Fat	3.4 - 4.8	4.0	3.7 - 5.0	4.4
Total sugar‡		1.5		2.9
Percent of original grain in various fractions				
Solubles (steepwater)	5.3 - 6.0	5.7	6.7 - 7.7	7.1
Starch fraction	60.7 -65.4	62.2	56.2 -59.3	58.1
Germ fraction	3.9 - 5.4	4.8	3.9 - 5.4	4.4
Gluten fraction	9.3 -14.9	12.9	13.9 -17.1	15.9
Fiber fraction	7.6 -12.3	9.8	6.5 -12.8	9.2
Total	90.7 -97.5	95.4	92.2 -97.8	94.7
Composition of fractions, % d.b.				
Protein in starch	0.26- 0.62	0.47	0.24- 0.27	0.26
Starch in gluten	29.5 -38.9	33.5	37.5 -44.1	40.8
Protein in gluten	42.9 -51.6	47.9	37.2 -41.5	38.1
Starch in fiber	22.3 -41.6	31.4	20.6 -32.9	27.3
Oil in germ	42.7 -57.8	53.3	50.6 -57.8	54.0
Percent recovery of whole kernel starch				
In starch fraction	86.3 -93.0	89.5	81.9 -87.1	84.1
In gluten fraction	4.2 - 7.2	6.0	7.9 -10.3	9.4
In fiber fraction	1.9 - 7.0	4.5	1.9 - 6.1	3.8

* Eight samples including Martin (2 samples), Combine Kafir 60 (2 samples), Combine Kafir 54T, Shallu, Redbine 66 and Double Dwarf Sooner.
† Six samples including Waxy Combine Kafir 60 (2 samples), Texioca 54, Double Dwarf White Sooner, and Kafir × White Feterita.
‡ As dextrose after inversion of sucrose. Determined only on Texioca 54 (waxy) and its non-waxy counterpart Combine Kafir 54T.

Table 3.—Colors of laboratory prepared starches.

Variety name	Color rating	Plant color	Pericarp color
Pinkish starches			
Texas Combine Kafir 60	1.5	Black	Tan
Commercial (Martin)	2	Black	Red brown
Martin (Lubbock)	3	Black	Red brown
Martin (Corpus Christi)	3	Black	Red brown
D.D. Yellow Sooner Milo	3.5	Black	Brown
Yellowish starches			
Shallu	1	Tan	White
Kafir × White Feterita, waxy	1	Tan	White
Texioca 54 (Waxy Kafir)	2	Tan	Tan
Texas Combine Kafir 60 (waxy)	3	Tan	Tan
Sooner Milo, D.D. White (waxy)	3	Tan	Tan
Texas Combine Kafir 60	3.5	Tan	Tan
Texas Combine Kafir 60	3.5	Tan	Tan

of the raw grain between waxy and non-waxy varieties was found except in the sugar content. The latter difference, which is also found in a comparison of waxy and regular corn (8), resulted in consistently higher yields of steeping solubles (steepwater) from the waxy types.

The regular or non-waxy varieties, which included two samples each of Martin Combine Milo, and Texas Combine Kafir 60 and one sample each of Texas Combine Kafir 54T, Shallu, Redbine 66 and Double Dwarf Sooner, gave consistently higher starch yield than the waxy varieties. The latter group included two samples of Waxy Combine Kafir 60 and one each of Texioca 54 (Waxy Combine Kafir 54), Double Dwarf Waxy White Sooner, and a selection out of a Kafir × White Feterita cross. It is significant that the ranges of starch yield for the waxy and regular groups did not overlap. The major reason for the lower starch yield from the waxy varieties was the higher yield of gluten caused by a greater starch content. Gluten from waxy varieties contained on the average 7.3% more starch which accounted for 3.4% more of the whole kernel starch than the average of the non-waxy varieties. It is believed that in commercial operation with centrifuges for separation of starch and gluten the recovery of starch from waxy grain sorghum can be made to approach that of the regular varieties. The significantly lower protein content of the starch from the waxy varieties was particularly encouraging because of similarity with protein content of corn starch.

No significant differences were found in the fiber or germ fractions between waxy and non-waxy varieties. Fiber fraction includes pericarp, aleurone and unmilled pieces of endosperm that will not pass the silk screens. Starch content of the fiber fraction is indicative of the completeness of the milling operation and may be a reflection of the hardness of the kernel. Within the regular starch varieties the high figures for starch in fiber belong to the combine Kafirs; the two Combine Kafir 60 samples averaged 34.4% starch in fiber while Combine Kafir 54T contained 41.6%. These varieties have proved to be consistently harder to mill than Martin variety. Much trouble was also encountered in germ separation by these two varieties. The degermination grist had to be divided into smaller portions than with Martin in order to allow germ to be floated away from fiber on the starch slurry. Shallu variety, which appears to have a very hard endosperm gave surprisingly good wet milling results. Fiber yield and starch content in fiber from Shallu was lowest of the regular varieties. Starch yield was low (60.7%) and gluten yield high (14.5%), but protein in starch was average (0.45%). The gluten of Shallu seems to be heavier than that of other varieties because it did not readily flow off the table but settled instead on the starch. It had to be washed off with a large volume of water in the squeegee operation; hence squeegee fraction yield was higher than yield of gluten fraction—just the reverse of other varieties. This fact is hidden in the combining of the gluten and squeegee fractions in the present data under "gluten". This behavior had been verified with several samples of Shallu milled subsequently to the data reported in table 2.

No very significant differences in wet milling properties among the waxy varieties was observed. Texioca 54 gave results slightly above the average of the group while Combine Kafir 60 was slightly below the average of the group. Waxy Sooner Milo was the only variety included of diverse origin but it gave results very similar to the waxy kafirs.

Starch color.—As indicated previously, the color of finished starch is an important quality characteristic, pure white being the ultimate objective. Starches prepared from 11 samples of grain sorghum were compared visually for relative color intensity and hue. One sample of commercial starch manufactured at Corpus Christi was included. Color intensity was rated numerically from zero, the intensity assigned to white magnesium oxide. It was found that the starches could be classified into two color groups—those having a pinkish hue and those having a yellowish hue. Results are shown in table 3. The color hue of the starches appeared to be most closely related to the occurrence of black or purple pigments which occur in the glumes and other vegetative portions of the sorghum plant. These pigments, known to the sorghum breeder as plant pigments (13), may have stained the pericarp during ripening and during steeping leached into the starch. The pericarp color was not without effect, however, as indicated by the lighter intensity of the starch from the Texas Combine Kafir 60 with black plant color and tan pericarp, as compared with the Martin samples which bear the red-brown pericarp. The varieties having tan plant color and white pericarp gave the brightest starches. Among the yellowish starches, the high intensity of the two Combine Kafirs was due to the presence of a greenish color. This was traced back to a green color on the seeds which was presumably chlorophyll. The yellowish starches with ratings of 2 are comparable to good quality commercial corn starch.

Since this work was done, a spectrophotometric reflectance method based on the C.I.E. tristimulus concept has been

applied to several of the starches listed in table 3.[3] The commercial sample of Martin starch had a dominant wave length of 578 mμ which was found to be characteristic of all starches from sorghums having black plant color. Purity was 2.0% and luminous reflectance 95.6%. Texioca 54 starch had a dominant wavelength of 571 mμ which was found to be characteristic of all starches prepared from varieties having tan plant color. Purity was 1.0% and luminous reflectance 98.2% indicating a very bright starch. Comparisons were made against C.I.E. Illuminant C.

The results reported here are indicative of the progress that has been made in the commercial and experimental wet milling of grain sorghum varieties. Much progress is still to be expected in the field of grain sorghum improvement. As new and promising varieties of grain sorghum are developed and old varieties improved, their early laboratory evaluation can lead to improved industrial utilization of this important crop.

SUMMARY

The commercial wet milling of grain sorghum as a new raw material for starch production has had to overcome several problems resulting from properties of grain sorghum not common with corn. Among these properties are the small, round shape of the kernel, the large proportion of horny endosperm, a dense peripheral endosperm layer, lower oil and higher wax content, lack of carotenoid pigments in the endosperm and the presence of red and brown pigments in the pericarp. Commercial experience has indicated the undesirability of Hegari or other varieties that have a pigmented seed coat (undercoat). Soft seeded varieties such as Plainsman and Caprock have given starches of lower protein content and lower hot paste viscosity while the more widely available, hard seeded, Martin variety has given starch of higher protein content and higher viscosity. In laboratory wet milling trials the waxy starch varieties differed from regular starch varieties mainly in giving a higher steeping solubles yield, lower starch and higher gluten yields, and a lower protein content in finished starch. Starch color was influenced by pericarp color and the presence of black or purple pigments in the glume. Plants having black plant color produced pinkish starches while those lacking this pigment were yellowish. Color intensity was affected by pericarp colors brown, red, tan and white.

[3] Smith, R. J., and Conway, T. F. Dry products color methods. Unpub. report. Corn Products Refining Co., Argo, Ill. June 1954.

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Testing For Combining Ability in Bromegrass[1]

R. P. Knowles[2]

SINCE 1945 extensive use has been made of open-pollination progenies in the evaluation of selections of various perennial grasses at the Forage Crops Laboratory, Saskatoon, Saskatchewan. Open-pollination progenies have been used in preference to polycross progenies, as seed for testing could be obtained directly from the breeding nurseries or from replicated clonal nurseries. As isolation was disregarded and replication of clones limited, some doubt arises as to whether open-pollination progenies uniformly reflect the breeding value of selections. This paper reviews investigations in bromegrass bearing on the use of open-pollination progenies as a technique for the appraisal of selected plants entering the breeding program.

[1] Contributiton of the Division of Forage Crops, Experimental Farms Service, Canada Dept. of Agriculture. Rec. for publication July 24, 1954.

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LITERATURE

Several studies with bromegrass have shown the relationship of open-pollination progenies to other types of progenies and parent clones. Knowles (5) found non-significant correlation coefficients of +0.44 and +0.68 between forage yields of open-pollination progenies and controlled crosses. The regression of open-pollination progenies on parental clones for forage yield was 0.17. McDonald *et al.* (7) reported a highly significant correlation of +0.54 between parent and open-pollination progenies as com-

pared to a non-significant correlation of +0.16 between parent clones and first generation inbred progenies. Regressions of open-pollination progenies on parents were 0.329 for yield of forage, 0.323 for spread, and 0.433 for plant height. Hawk and Wilsie (2) noted significant positive correlations between the yields of parents and open-pollination progenies. Regression analyses indicated 20 to 25% of the variability in forage yields of progenies attributable to parent clones. Hittle (3) observed the relationship between polycross progenies and parent clones. Doubling regressions of progenies on parents based on results of 2 years gave heritability values of 0.819 for plant height, 0.407 for hay vigor, and 0.564 for aftermath vigor. One year results gave heritability values of 0.960 for brown spot infection and 0.664 for spread. Wide fiducial limits accompanied these heritability values.

Open-pollination progenies in the above studies were obtained from clonal or polycross nurseries with various numbers of replications of clones. Hittle[3] found significant differences in the performances of polycross progenies according to the location of the clones in the polycross nursery in which the seed was produced. Knowles (5) compared open-pollination progenies grown from seed produced in different replicates of a clonal nursery. A significant strain × source of seed interaction was observed for the creeping habit but none for forage yield. Wit (10) reported that 40% of the fertilization of perennial ryegrass resulted from the pollination of two adjacent clones. He concluded that open-pollination progenies from unreplicated clones would give very unreliable information on the breeding potentialities of the mother clones. Gutierrez,[8] using inbred lines of corn with marker genes, found that random pollination was not achieved in the polycross even when considerable replication of lines was provided.

Little information has been accumulated in perennial forage crops on the yields of synthetics as related to previous tests of combining ability. Tysdal and Crandall (6) obtained yields of 87 to 116% of checks for eight synthetics of alfalfa. Yields of the synthetics were in good agreement with expectations from previous polycross progeny tests. Graumann (1) found alfalfa synthetics derived from as few as three clones to yield more in the first generation than synthetics containing from four to six clones. In advanced generation of synthesis, however, the yields of all synthetics were at a common level little above that of the check variety.

Johnson and Hoover (4) found first generation synthetics of sweet clover to yield from 93 to 148% of the check variety. These yields were in good agreement with those expected on the basis of previous open-pollination progeny tests.

Weiss *et al.* (9) did not observe any relation between number of plants entering synthetics of orchard grass and subsequent yields of these synthetics. Yields in the second generation of synthesis were on the average very similar to those of the syn-1.

MATERIALS AND METHODS

Throughout this paper open-pollination progenies shall be referred to as O.P. progenies. From 1945 to 1953 ten yield trials were made of O.P. progenies of selected bromegrass plants. A total of 128 progenies of selections were tested. Plants for the most part were selected from northern and southern varieties or strains which had undergone no previous breeding. However 39 of the 56 progenies in test 1 were from inbred lines. Twelve of the 22 progenies entering test 7 were from plants with inbreeding in their histories.

For tests 1 and 6 the O.P. seed was harvested from unreplicated single plant selections growing in space-planted nurseries. In other tests O.P. seed was obtained from clonal nurseries with 3–6 replications of clonal rows. No attempt was made to isolate clonal material from other fields or nurseries. Selfing was accomplished by the use of parchment paper bags 3 by 12 inches. Controlled crosses were made by transferring panicles from pollen parents to isolation bags on seed parents in advance of flowering. Detached panicles were placed in vials of water throughout the flowering period and replaced with fresh panicles if wilting occurred.

Tests 1, 2, 3, 4, 5, and 10 were seeded tests of O.P. progenies designed to give seed and forage yields under ordinary field-type planting. Plots in these trials were 3 by 20 feet and consisted of three rows spaced 1 foot apart. Six-replicate lattice designs were employed except in test 1 where three replications were used. Seed and forage yields were obtained from the same plot areas by one harvest at an early seed maturity stage.

Tests 6, 7, 8, and 9 were comparisons of O.P. progenies, selfed progenies and clones of parent plants. Space planted row plots with four to six replications were used. Clones were randomized with progenies in test 6 while in tests 7, 8, and 9 clones were tested in separate tests adjacent to tests of progenies. In tests 8 and 9 forage yields were significantly correlated with degree of creeping and were corrected by covariance analysis for degree of creeping.

Yields for most tests were for a 2-year period. In all tests, forage and seed yields were reported as percentages of those of the northern commercial check.

EXPERIMENTAL RESULTS

Combining Ability of Selected Plants as Shown by Open-pollination Progenies

Tables 1 and 2 indicate the range of forage and seed yields of O.P. progenies of plants of bromegrass selected visually in single-plant nurseries for good forage and seed habit. Selections in inbred lines were from lines that had been selfed for from four to six generations. Selections from varieties were from both northern and southern varieties of bromegrass.

Tables 1 and 2 show marked differences in the combining ability of bromegrass plants on the basis of the yields of their O.P. progenies. For test 1, which involved only three replications, these differences were not significant. Seed yields of progenies showed much greater range than did forage yields. Apparently, the possibilities of improvement in seed production are much greater than in forage production. The frequency of plants with good forage or seed producing progenies was similar in inbred lines and varieties. It would appear that plants with superior combining ability could be isolated without recourse to inbreeding. As the average forage yield of O.P. progenies was below that of the commercial check, the success of initial selection in spaced-plant nurseries was not too great. Picking plants at random might have yielded as many plants with superior forage production. For seed, however, the average yield of progenies was above that of the commercial check, thus indicating some success in selection.

Comparison of Open-pollination Progenies and Test-crosses

One test of the reliability of O.P. progenies as indicators of combining ability was a comparison of O.P. progenies of nine plants with test-crosses involving the same plants. Test-cross seed was obtained by pollinating three self-sterile tester plants with pollen from each of nine selections. A six-replicate test with plots of 11 spaced plants was used. Yields were based on a single cutting in the first crop year. No correction of yields for degree of creeping was made as strains showed very moderate creeping at the first harvest. Table 3 presents correlation coefficients showing the relation of O.P. progeny yields of selections to test-cross yields.

Fairly high correlations were found between the yields of O.P. progenies and test-crosses for two of the three tester plants as well as for the average yield of the three test-crosses. If average test-cross performance can be considered a good index of the general combining ability of selections, it would appear from this trial that O.P. progenies were moderately satisfactory for screening selected bromegrass plants.

[8] Gutierrez, Mario Gutierrez. Factors affecting randomness of mating in isolated polycross plantings of maize. Unpub. Ph.D. thesis. Iowa State College library, Ames, Iowa. 1952.

Table 1.—Forage yields of O.P. progenies of selected plants of bromegrass.

Test No.	Source of selection	Distribution of progeny yields as percent of northern commercial check							No. of selections	L.S.D. percent (P=0.05)
		71–80	81–90	91–100	101–110	111–120	121–130	Avg.		
1	Inbred lines	4	14	11	9	1	—	90.3	39	N.S.
1	Varieties	—	12	3	2	—	—	90.0	17	N.S.
2	Varieties	—	—	—	12	5	1	109.8	18	11
3	Varieties	—	—	6	11	5	—	104.1	22	8
		4	26	20	34	11	1	97.1	96	—

Table 2.—Seed yields of O.P. progenies of selected plants of bromegrass.

Test No.	Source of selection	Distribution of progeny yields as percent of northern commercial check						No. of selections	L.S.D. percent (P=0.05)
		0–50	51–100	101–150	151–200	201–250	Avg.		
1	Inbred lines	2	16	15	4	2	105.7	39	N.S.
1	Varieties	—	7	9	1	—	104.6	17	N.S.
3	Varieties	—	4	15	3	—	122.1	22	21
Totals and average		2	27	39	8	2	110.1	78	—

Comparison of Open-pollination Progenies from Different Clonal Sources

Another check on the reliability of O.P. progenies consisted of comparisons of duplicate O.P. progenies arising from the use of O.P. seed of different replicates of a clonal nursery. If replication in the polycross or clonal nursery is important in assuring random pollination, then an interaction of O.P. progenies and source of seed in the clonal nursery would be expected. Test 4 included the O.P. progenies of eight selections. For each selection, seed from replicate 1 of a replicated randomized clonal nursery was used to produce one O.P. progeny, and seed from replicate 2 of the clonal nursery was used to produce a second O.P. progeny. Test 5 was a similar trial involving duplicate O.P. progenies of 12 selections. In both tests 4 and 5, variance analyses of hay yields of O.P. progenies showed significance ($P = 0.01$) for selections but not for the selection $\times$ clonal source of seed interaction.

In test 4 the O.P. progenies of eight clones in one replicate of the clonal nursery showed a correlation of +0.87 with the progenies derived from the same clones in the second replicate of the clonal nursery. For test 5 the O.P. progenies of 12 clones in one replicate of the clonal nursery gave a correlation of +0.60 with O.P. progenies of the same clones growing in another replicate of the clonal nursery.

Strains entering tests 4 and 5 also entered progeny tests 2 and 3 which were seeded with O.P. seed bulked from all replicates of clonal nurseries. Tests 2 and 3 were situated in different field locations from tests 4 and 5 and were harvested to some extent for different years. A nonsignificant correlation coefficient of +0.65 was obtained when average strain yields in test 4 were compared with those in test 2. The comparison of tests 5 and 3 gave a significant correlation coefficient of +0.65. These tests indicate that considerable confidence may be attached to the performance of O.P. progenies grown from seed harvested from single plants or single clonal rows. However, for critical comparisons, progenies grown from composite seed of two or more replications of clones in polycross or clonal nurseries would seem preferable.

Table 3.—Correlation coefficients showing the relationship of open-pollination progeny forage yields to test-cross yields for nine plants (Test 6).

Comparison	Correlation coefficient
O.P. progeny and cross with tester A	+0.63
O.P. progeny and cross with tester B	+0.76*
O.P. progeny and cross with tester C	+0.81*
O.P. progeny and average yield of A, B and C crosses	+0.79*

* Significant correlation $P = 0.05$.

Regressions of Progenies on Parents

Regressions of progenies on parent clones were determined for the important agronomic characters of forage and seed production and degree of creeping. The degree of heritability is important in indicating the type of gene action responsible for various characters and the degree of success which might be expected to attend various breeding procedures. Table 4 presents regression coefficients for three characters of bromegrass.

Highest relationships between parents anrd progenies were noted for the creeping-rooted habit and lowest relationships for seed production. Forage production showed an intermediate position. It follows that heritability was high for the creeping habit, moderate for forage production, and low for seed production. Clonal nurseries would appear useful in breeding for habit of creeping. For seed production, on the other hand, clonal performance would be expected to give meagre improvement, and progeny trials would be necessary to evaluate selections. Progeny tests also would be required in the evaluation of selections for forage produc-

pared to a non-significant correlation of +0.16 between parent clones and first generation inbred progenies. Regressions of open-pollination progenies on parents were 0.329 for yield of forage, 0.323 for spread, and 0.433 for plant height. Hawk and Wilsie (2) noted significant positive correlations between the yields of parents and open-pollination progenies. Regression analyses indicated 20 to 25% of the variability in forage yields of progenies attributable to parent clones. Hittle (3) observed the relationship between polycross progenies and parent clones. Doubling regressions of progenies on parents based on results of 2 years gave heritability values of 0.819 for plant height, 0.407 for hay vigor, and 0.564 for aftermath vigor. One year results gave heritability values of 0.960 for brown spot infection and 0.664 for spread. Wide fiducial limits accompanied these heritability values.

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MATERIALS AND METHODS

Throughout this paper open-pollination progenies shall be referred to as O.P. progenies. From 1945 to 1953 ten yield trials were made of O.P. progenies of selected bromegrass plants. A total of 128 progenies of selections were tested. Plants for the most part were selected from northern and southern varieties or strains which had undergone no previous breeding. However 39 of the 56 progenies in test 1 were from inbred lines. Twelve of the 22 progenies entering test 7 were from plants with inbreeding in their histories.

For tests 1 and 6 the O.P. seed was harvested from unreplicated single plant selections growing in space-planted nurseries. In other tests O.P. seed was obtained from clonal nurseries with 3–6 replications of clonal rows. No attempt was made to isolate clonal material from other fields or nurseries. Selfing was accomplished by the use of parchment paper bags 3 by 12 inches. Controlled crosses were made by transferring panicles from pollen parents to isolation bags on seed parents in advance of flowering. Detached panicles were placed in vials of water throughout the flowering period and replaced with fresh panicles if wilting occurred.

Tests 1, 2, 3, 4, 5, and 10 were seeded tests of O.P. progenies designed to give seed and forage yields under ordinary field-type planting. Plots in these trials were 3 by 20 feet and consisted of three rows spaced 1 foot apart. Six-replicate lattice designs were employed except in test 1 where three replications were used. Seed and forage yields were obtained from the same plot areas by one harvest at an early seed maturity stage.

Tests 6, 7, 8, and 9 were comparisons of O.P. progenies, selfed progenies and clones of parent plants. Space-planted row plots with four to six replications were used. Clones were randomized with progenies in test 6 while in tests 7, 8, and 9 clones were tested in separate tests adjacent to tests of progenies. In tests 8 and 9 forage yields were significantly correlated with degree of creeping and were corrected by covariance analysis for degree of creeping.

Yields for most tests were for a 2-year period. In all tests, forage and seed yields were reported as percentages of those of the northern commercial check.

[3] Gutierrez, Mario Gutierrez. Factors affecting randomness of mating in isolated polycross plantings of maize. Unpub. Ph.D. thesis. Iowa State College library, Ames, Iowa. 1952.

EXPERIMENTAL RESULTS

Combining Ability of Selected Plants as Shown by Open-pollination Progenies

Tables 1 and 2 indicate the range of forage and seed yields of O.P. progenies of plants of bromegrass selected visually in single-plant nurseries for good forage and seed habit. Selections in inbred lines were from lines that had been selfed for from four to six generations. Selections from varieties were from both northern and southern varieties of bromegrass.

Tables 1 and 2 show marked differences in the combining ability of bromegrass plants on the basis of the yields of their O.P. progenies. For test 1, which involved only three replications, these differences were not significant. Seed yields of progenies showed much greater range than did forage yields. Apparently, the possibilities of improvement in seed production are much greater than in forage production. The frequency of plants with good forage or seed producing progenies was similar in inbred lines and varieties. It would appear that plants with superior combining ability could be isolated without recourse to inbreeding. As the average forage yield of O.P. progenies was below that of the commercial check, the success of initial selection in spaced-plant nurseries was not too great. Picking plants at random might have yielded as many plants with superior forage production. For seed, however, the average yield of progenies was above that of the commercial check, thus indicating some success in selection.

Comparison of Open-pollination Progenies and Test-crosses

One test of the reliability of O.P. progenies as indicators of combining ability was a comparison of O.P. progenies of nine plants with test-crosses involving the same plants. Test-cross seed was obtained by pollinating three self-sterile tester plants with pollen from each of nine selections. A six-replicate test with plots of 11 spaced plants was used. Yields were based on a single cutting in the first crop year. No correction of yields for degree of creeping was made as strains showed very moderate creeping at the first harvest. Table 3 presents correlation coefficients showing the relation of O.P. progeny yields of selections to test-cross yields.

Fairly high correlations were found between the yields of O.P. progenies and test-crosses for two of the three tester plants as well as for the average yield of the three test-crosses. If average test-cross performance can be considered a good index of the general combining ability of selections, it would appear from this trial that O.P. progenies were moderately satisfactory for screening selected bromegrass plants.

Table 1.—Forage yields of O.P. progenies of selected plants of bromegrass.

Test No.	Source of selection	Distribution of progeny yields as percent of northern commercial check							No. of selec-tions	L.S.D. percent (P = 0.05)
		71–80	81–90	91–100	101–110	111–120	121–130	Avg.		
1	Inbred lines	4	14	11	9	1	—	90.3	39	N.S.
1	Varieties	—	12	3	2	—	—	90.0	17	N.S.
2	Varieties	—	—	—	12	5	1	109.8	18	11
3	Varieties	—	—	6	11	5	—	104.1	22	8
		4	26	20	34	11	1	97.1	96	—

Table 2.—Seed yields of O.P. progenies of selected plants of bromegrass.

Test No.	Source of selection	Distribution of progeny yields as percent of northern commercial check						No. of selec-tions	L.S.D. percent (P = 0.05)
		0–50	51–100	101–150	151–200	201–250	Avg.		
1	Inbred lines	2	16	15	4	2	105.7	39	N.S.
1	Varieties	—	7	9	1	—	104.6	17	N.S.
3	Varieties	—	4	15	3	—	122.1	22	21
Totals and average		2	27	39	8	2	110.1	78	—

Comparison of Open-pollination Progenies from Different Clonal Sources

Another check on the reliability of O.P. progenies consisted of comparisons of duplicate O.P. progenies arising from the use of O.P. seed of different replicates of a clonal nursery. If replication in the polycross or clonal nursery is important in assuring random pollination, then an interaction of O.P. progenies and source of seed in the clonal nursery would be expected. Test 4 included the O.P. progenies of eight selections. For each selection, seed from replicate 1 of a replicated randomized clonal nursery was used to produce one O.P. progeny, and seed from replicate 2 of the clonal nursery was used to produce a second O.P. progeny. Test 5 was a similar trial involving duplicate O.P. progenies of 12 selections. In both tests 4 and 5, variance analyses of hay yields of O.P. progenies showed significance ($P = 0.01$) for selections but not for the selection $\times$ clonal source of seed interaction.

In test 4 the O.P. progenies of eight clones in one replicate of the clonal nursery showed a correlation of $+0.87$ with the progenies derived from the same clones in the second replicate of the clonal nursery. For test 5 the O.P. progenies of 12 clones in one replicate of the clonal nursery gave a correlation of $+0.60$ with O.P. progenies of the same clones growing in another replicate of the clonal nursery.

Strains entering tests 4 and 5 also entered progeny tests 2 and 3 which were seeded with O.P. seed bulked from all replicates of clonal nurseries. Tests 2 and 3 were situated in different field locations from tests 4 and 5 and were harvested to some extent for different years. A nonsignificant correlation coefficient of $+0.65$ was obtained when average strain yields in test 4 were compared with those in test 2. The comparison of tests 5 and 3 gave a significant correlation coefficient of $+0.65$. These tests indicate that considerable confidence may be attached to the performance of O.P. progenies grown from seed harvested from single plants or single clonal rows. However, for critical comparisons, progenies grown from composite seed of two or more replications of clones in polycross or clonal nurseries would seem preferable.

Table 3.—Correlation coefficients showing the relationship of open-pollination progeny forage yields to test-cross yields for nine plants (Test 6).

Comparison	Correlation coefficient
O.P. progeny and cross with tester A	+0.63
O.P. progeny and cross with tester B	+0.76*
O.P. progeny and cross with tester C	+0.81*
O.P. progeny and average yield of A, B and C crosses	+0.79*

* Significant correlation $P = 0.05$.

Regressions of Progenies on Parents

Regressions of progenies on parent clones were determined for the important agronomic characters of forage and seed production and degree of creeping. The degree of heritability is important in indicating the type of gene action responsible for various characters and the degree of success which might be expected to attend various breeding procedures. Table 4 presents regression coefficients for three characters of bromegrass.

Highest relationships between parents anrd progenies were noted for the creeping-rooted habit and lowest relationships for seed production. Forage production showed an intermediate position. It follows that heritability was high for the creeping habit, moderate for forage production, and low for seed production. Clonal nurseries would appear useful in breeding for habit of creeping. For seed production, on the other hand, clonal performance would be expected to give meagre improvement, and progeny trials would be necessary to evaluate selections. Progeny tests also would be required in the evaluation of selections for forage produc-

tion although critical clonal tests would yield some information on breeding value. Regressions noted here are in fair agreement with those reported by McDonald *et al.* (7) and Hittle (3) for bromegrass.

Synthetics Formed on the Basis of Open-pollination Progeny Performance

Five synthetics of bromegrass were formed on the basis of O.P. progeny tests. These synthetics have thus far been tested only in the first generation of synthesis. Table 5 summarizes the results of synthetic performances.

Considerable evidence for the success of selection is shown by the yields of synthetics particularly with respect to seed production. Synthetics C-3 and C-20 were formed on the basis of a 3-replicate test of O.P. progenies where the differences shown in forage and seed yields were not significant. Neither synthetic C-3 or C-20 excelled the check in forage production but both did for seed production. Synthetic C-20 contained the same four plants as synthetic C-3 plus four additional plants with somewhat lower combining ability as shown by O.P. progeny tests. The use of the smaller number of plants in synthetic C-3 resulted in better forage production but somewhat lower seed production than in C-20. Synthetics S-4088, S-4091, and S-4092 were formed on the basis of more elaborate progeny testing. Two of these synthetics showed significant improvement over the check in both forage and seed production. It is interesting to note that seed yields of synthetics generally were above those of open-pollination progenies thus indicating a possible recombination of good yielding factors from the selected clones constituting them.

DISCUSSION

Open-pollination progenies appear to be a convenient and reasonably reliable type of progeny for the identification of superior plants of bromegrass. In these studies, open-pollination progenies of selected plants showed fair relationships to test-crosses with respect to forage production. High regressions of open-pollination progenies on parents for certain characteristics such as the creeping rooted habit lend confidence in the ability of these progenies to reflect parent characteristics. Superior first generation synthetics have been formed on the basis of open-pollination progeny testing.

Open-pollination progenies in these tests generally were obtained from clonal nurseries with two to six replications of clones in randomized blocks. Although progenies grown from seed of different replicates correlated fairly well, the use of seed from at least three replicates of clonal nurseries would seem desirable. Extensive replication of clones and isolation of clones as suggested for polycross nurseries (10) would appear unnecessary in the production of seed for preliminary progeny testing. Fairly strong winds during the pollination period are common at Saskatoon and might have provided more uniform pollination of selections than would occur in other areas. The average wind velocity at Saskatoon for the 7-day flowering period July 1 to July 7 for the years 1944 to 1953 was 12.5 per hour.[4]

The heritability of various characters may be obtained by doubling regressions of open-pollination progenies on parent clones. Such a procedure is similar to doubling of intra-

[4] Weather records, Department of Physics, University of Saskatchewan.

Table 4.—Regressions of progenies on parent clones of bromegrass for forage and seed yields and for creeping habit.

Test No.	No. of comparisons	Regression of progeny on parent shown by		
		O.P. progeny	Test-cross progeny	Self-progeny
		Forage yields		
6	9	0.34 ±0.18	0.29 ±0.19	—
7	22	.21 ± .12	—	—
8	15	.12 ± .16	—	−0.14 ±0.20
9	23	.23 ± .12	—	0.45 ± .04
2 and 9*	22	.33 ± .09	—	—
8 and 10*	9	.25 ± .27	—	—
		Seed yields		
7	22	0.11 ±0.10	—	—
2 and 9*	22	.08 ± .02	—	—
8 and 10*	9	.10 ± .02	—	—
		Degree of creeping		
7	22	0.45 ±0.07	—	—
8	15	.34 ± .13	—	0.67 ±0.13
9	23	.62 ± .25	—	.39 ± .16

* Clones grown as spaced plants and O.P. progenies in seeded triple row plots in separate tests; other comparisons made in single tests under space-planted conditions.

Table 5.—Yields of first generation synthetics of bromegrass formed on the basis of open-pollination progeny yields.

Synthetic	No. of plants entering synthetic	Avg. yield as percent of check	
		Synthetic	O.P. Progeny average
		Forage yield	
C-3	4	106	108
C-20	8	94	106
S-4088	5	112*	113
S-4091	6	112*	115
S-4092	7	110	111
		Seed yield	
C-3	4	156*	143
C-20	8	177*	134
S-4088	5	174*	133
S-4091	6	144*	126

* Significantly above the commercial check ($P = 0.05$).

sire correlations or regressions of daughter on dam suggested by Lush (6) for heritability determinations in animals. It is assumed that in the formation of open-pollinated seed of bromegrass, there would be uniformity of pollination of selections by a mass of field pollen. Heritability values for forage production on the basis of regression values noted in table 5 would range from 24 to 68%. Heritability of seed production would range from 11 to 22% and the creeping-rooted habit from 68 to 100%. High standard error values for regression coefficients limit the reliability of these heritability determinations. Small amounts of selfing, characteristic of bromegrass, also may have exaggerated these heritability values.

The performance of synthetics in these tests indicates that an improvement in the forage yields of bromegrass may be obtained consistent with gains noted in other forage

crops. Final evaluation of synthetics, however, must await the testing of synthetics in more advanced generations. The gain of 12% in forage yields for two synthetics is particularly gratifying if coupled with other attributes such as high seed yields and disease resistance. A higher level of hay yields may be obtained by recurrent selection in present synthetics or progeny testing of a larger number of original selections. The growing of large source nurseries would seem unnecessary in view of the evidence in these studies that visual selection in the original nursery was not very successful. Rather, attention should be directed to progeny testing.

Indications have been obtained that where as many as eight selections were included in synthetics that one or two selections were not performing satisfactorily. That is, synthetic seed from these selections gave rise to low yielding plants in comparison with plants grown from synthetic seed of other selections. Either these selections were showing a specific reaction in the synthetic or the original progeny tests were in error. Eliminating such plants from the synthetic should lead to better production of the synthetic. Since relatively small gains are to be expected in forage yields of synthetics, it is essential that good precision be maintained in progeny tests and that row spacings and methods of seeding conform to ordinary field conditions.

Selfing does not appear necessary in a breeding program for bromegrass. In these studies the combining ability ratings of phenotypically selected plants in inbred lines (tables 1 and 2) were not markedly higher than those of selected plants in commercial varieties. An additional test of combining ability involving 24 first generation inbred lines indicated a lower frequency of superior open-pollinated progenies of inbred lines than that found among open-pollination progenies of parents of the inbred lines. Sixteen plants chosen from among these 24 inbred lines on the basis of plant vigor and type showed no superiority in combining ability over the original selections. Since bromegrass is low in self-fertility, a breeding program based on inbred lines also results in the discard of many plants which may have high combining ability. No consistent relationship was found in these studies between self-fertility of parent clones and their combining ability.

SUMMARY

Results from ten tests of bromegrass progenies over the period 1945 to 1953 were reviewed to find the usefulness of open-pollination progenies in assessing the combining ability of selected plants.

Open-pollination progeny tests of selected plants from commercial varieties and strains indicated a moderate range for forage production and wide variability for seed production. A test of nine selections showed a correlation of +0.79 between forage yields of open-pollination progenies of selections and the average forage yield of three test-crosses of selections. Open-pollination seed from clones growing in different nursery positions gave progenies with rather similar forage yields. Several first generation synthetics formed on the basis of open-pollination progeny performance showed significantly higher forage and seed yields than commercial check varieties.

Regression of open-pollination progenies on parents varied from 0.12 to 0.34 for forage production, 0.08 to 0.11 for seed production, and 0.34 to 0.62 for degree of creeping rootedness.

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Optimum Size of Sample for Hand Separation of Forage Crop Mixtures into Their Component Species in Small Plot Experiments[1]

R. G. Petersen and D. S. Chamblee[2]

IN SMALL plot experiments with forage crop mixtures, it is often desirable to obtain an accurate estimate of the effect of treatment or environment on the botanical composition of the mixture. Although several more rapid procedures have been proposed (4, 11) the most accurate estimate of botanical composition is obtained by hand separating a sample of the forage from the plot into its component species (1, 10). In addition, a sample must be hand separated if chemical analyses are to be run on the individual species in the mixture. Since hand separation is an expensive procedure, the sample to be analyzed should be selected in a way that provides the maximum accuracy at a minimum cost.

Much of the previous work on size of sampling unit in forage investigations has been concerned with estimating the botanical composition of native ranges. Pechanec and his co-workers (6, 7) have rather extensively investigated sampling procedures for the botanical evaluation of range mixtures. Their results, however, are not directly applicable to small plot work. Sprague and Myers (10), working with small plot experiments, concluded that a sample 2 inches wide and as long as the plot should be clipped from a random location in the plot. One-fourth of the sample should then be hand separated to estimate the botanical composition of the plot. They found that the accuracy of estimation was increased more by restricting the number of samples per plot to one and increasing the number of plots per treatment than by increasing the sampling rate within the plot. However, costs were not considered in arriving at these conclusions.

The yield of forage mixtures in many small plot experiments is estimated from a strip clipped with a mower from the center of the plot. This paper is concerned with determining the size of subsample to be selected from this yield-strip sample to obtain an estimate of the botanical composition of the plot. No attempt was made in this study to investigate plot size and shape, since this subject has received considerable attention from other workers (3, 8, 9).

MATERIALS AND METHODS

Two forage crop experiments were used in this investigation; in one several rates of nitrogen were studied, and in the other various management practices. Both were uniformly seeded with a mixture of white clover, low hop clover, brome grass and orchard grass during the fall prior to this study. In the nitrogen experiment, certain of the plots had received nitrogen fertilizer, at rates of 0, 50, or 100 pounds of elemental nitrogen per acre, on March 15, 1945, 6 weeks before the plots were harvested. In the management experiment, no supplemental fertilizer had been applied but certain plots had been harvested 1 month prior to the clipping used for this study.

The individual plots in both experiments were 5 by 25 feet in size, and a yield-strip sample 2 feet wide and 23 feet long was cut from the center of each plot with a sickle-bar power mower. The fresh herbage from this strip was immediately raked, bagged and brought into the laboratory where green weights were recorded and random subsamples taken for hand separation. Each subsample was weighed to insure that all would contain the same quantity of fresh herbage.

In the nitrogen experiment, consisting of 42 plots, five subsamples, each containing 20% of the total herbage, were chosen at random from seven of the yield-strip samples, while four subsamples, each containing 10% of the total herbage, were taken from the remaining 35 plot samples. In the management experiment, consisting of 21 plots, four 10% subsamples were randomly drawn from each yield-strip sample. Each subsample was hand separated into its component species and these components were oven dried. The average weight of the yield-strip samples for the nitrogen and management experiments was approximately 331 grams of oven-dry forage. The weight of each species was then expressed as a percent of the total dry weight of the subsample.

Statistical Theory and Methods

Theory.—The underlying principle involved in estimating the optimum size of subsample is that of minimizing the total cost for a given variance or, alternatively, minimizing the variance for a given cost. With the subsampling procedure used in this study the variance, $V_{\bar{x}}$, of a species mean (on a per subsample basis) is given by

$$V_{\bar{x}} = \frac{\sigma^2_r}{r} + \frac{\sigma^2_s}{rs} \qquad [1]$$

in which

σ^2_r is the species variation between plots (yield-strip samples) treated alike;

σ^2_s is the species variation from subsample to subsample within a plot (yield-strip sample);

r is the number of plots per treatment;

s is the number of unit subsamples per plot.

The total cost, $C_{\bar{x}}$, of obtaining an estimate of the botanical composition of the plots from a particular treatment at a single harvest may be expressed as

$$C_{\bar{x}} = rC_r + rsC_s \qquad [2]$$

where

C_r is the cost per plot if no subsamples are hand separated;

C_s is the cost of selecting and hand separating a unit subsample.

When the variance is of the form given by [1] and the total cost is described by [2] it can be shown (5) that the total cost will be a minimum if the number of unit subsamples is such that

$$s_{opt.} = \sqrt{\frac{C_r \sigma^2_s}{C_s \sigma^2_r}} \qquad [3]$$

where $s_{opt.}$ is the optimum subsampling rate, regardless of the number of plots per treatment.

Methods.—Estimates of the species variation between plots treated alike, σ^2_r, and of the variation between subsamples within yield-strip samples, σ^2_s, were obtained from the analyses of variance of the experimental data. An example of the type of analysis used for these experiments is shown in table 1.

Since the weight of each species was expressed as a percent of the subsample weight, there is no variation between treatments, between plots within treatments, nor between subsamples within plots. Hence the corresponding mean squares are zero.

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Table 1.—Analysis of variance of botanical composition of management experiment using four 10% subsamples per plot.

Source	d. f.	M. S.	Mean square is an estimate of
Between management treatments	6	0	
Between plots within treatments	14	0	
Between subsamples within plots	9	0	
Between species	4	15,511.41	
Species × treatments	4	268.69	
Species × plots within treatments	56	190.69	$(M.S.)_r = \sigma^2_s + s\sigma^2_r$
Species × subsamples within plots	252	19.93	$(M.S.)_s = \sigma^2_s$

Table 2.—Average botanical composition expressed as a percent of the total dry weight of the subsample.

Experiment	White clover	Low hop clover	Brome grass	Orchard grass	Weeds
Rate of N (10% subsamples)	34.0	26.3	4.5	24.8	10.4
Rate of N (20% subsamples)	36.2	23.9	4.7	25.4	9.7
Management (10% subsamples)	32.6	29.5	1.9	9.2	26.8

The variance components for each set of sampling conditions were computed from the relationships given in table 1. That is

$$\sigma^2_s = (M.S.)_s$$

$$\sigma^2_r = \frac{(M.S.)_r - (M.S.)_s}{s}$$

The cost of preparing the seed-bed, fertilizing, seeding and harvesting each of these experiments was estimated by considering the number of man-hours required for each operation and the cost of seed and fertilizer. From these estimates the average cost, C_r, of obtaining a yield-strip sample at a single harvest was determined. Records were kept of the time required to select and hand separate each subsample. The average cost, C_s, associated with hand separating a subsample was obtained from these records.

RESULTS

The average botanical composition of each of the experiments is shown in table 2. It will be noted that the legumes comprised about 60% of the total herbage of the plot, although this value varied between 44 and 78%. The nitrogen experiment yielded an average of 692 pounds of dry herbage per acre, and the management experiment yielded an average of 691 pounds of dry herbage per acre at this harvest.

Since the purpose of botanical analysis is to determine the relative proportion of each species regardless of the total plot yield, it is convenient to express the yield of each species as a percent of the total yield of forage. This was done in this investigation and an analysis of variance was run on these percentage values. Although there is a slight tendency for the variation of the percentages near 50% to be greater than that for the percentages near 0% and 100%, an examination of the data indicated no serious correlation between variances and means, consequently no transformation was used.

Estimates of the species variation between plots treated alike, σ^2_r, and of the species variation from subsample to subsample within a plot, σ^2_s, were obtained for each of the three sets of sampling conditions represented by the experimental data. These estimates are given in table 3.

Each of the subsamples drawn from the yield-strip sample represented a relatively large proportion of the herbage in the sample. It was thought advisable, therefore, to determine

Table 3.—Estimates of plot to plot variation, σ^2_r, and subsample of subsample variation, σ^2_s.

Experiment	σ^2_r	σ^2_s
Rate of N (10% subsamples)	49.03	17.89
Rate of N (20% subsamples)	42.59	11.47
Management (10% subsamples)	42.69	19.93

whether correcting for sampling from a finite population would appreciably affect the variance of a species mean. There was little difference between the corrected and the uncorrected values, however, and the correction was not used in obtaining the variances given in this paper.

From records kept during the course of investigation, it was estimated that the cost, C_r, associated with producing a plot and obtaining a yield-strip sample at the single harvest was approximately $1.50. Similarly the cost, C_s, of selecting and hand-separating a subsample containing 10% of the forage from the yield-strip was estimated to be approximately $0.50.

Using the above values for C_r and C_s and the estimates of the variance components given in table 3, the optimum size of subsample, $s_{opt.}$, was determined from the relationship given previously [3], that is

$$s_{opt.} = \sqrt{\frac{C_r\sigma^2_s}{C_s\sigma^2_r}}$$

For example, using the data from the management experiment, the optimum subsampling rate is

$$s_{opt.} = \sqrt{\frac{(1.50)\ (19.93)}{(0.50)\ (42.69)}}$$

$$s_{opt.} = 1.18 \text{ subsampling units}$$

$$s_{opt.} = 11.8\% \text{ of the yield-strip sample.}$$

Similarly, using the 10% subsample data from the nitrogen experiment, the optimum subsample size was found to be 10.2% of the yield-strip sample, while the optimum size was found to be 12.7% using the 20% subsample data from the same experiment.

It is interesting to note the variation in the total cost when a size of subsample other than the optimum is used. The variance of a species mean, $V_{\bar{x}}$, and the cost, $C_{\bar{x}}$, of obtaining an estimate of the botanical composition at a single harvest were computed for the case where the number of plots, or replications, per treatment is restricted to one (*c.f.* equations [1] and [2]). These values are shown in table 4. On considering equations [1] and [2] it will be seen that the variance, $V_{\bar{x}}$, or the cost, $C_{\bar{x}}$, under increased replication may be obtained by multiplying the appropriate item in table 4 by the number of replications under consideration.

It is apparent that as the size of subsample is increased, the variance decreases at a decreasing rate while the total cost increases at an increasing rate. If we define "amount of information" as the reciprocal of the variance (2) then the cost per unit of information, C_I, may be obtained as the product of the variance and the total cost. C_I was computed for each subsample size included in table 4. It will be noted that the cost per unit information is a minimum at the optimum sampling rate. In addition it is clear that the cost per unit of information, hence the cost of attaining a given degree of accuracy, is increased as the subsample size is made larger or smaller than the optimum.

The number of replications and the size of subsample necessary to estimate a species mean within a given level of accuracy were also computed. These results, based on the average variance of the two experiments used for this study, are presented in table 5 along with the total cost of obtaining a given level of accuracy under each sampling procedure.

For each level of accuracy, there is a minimum number of replications below which the desired level cannot be attained even if the entire yield-strip is hand separated. The results presented in table 5 indicate that at each level of accuracy the total cost approaches a minimum as the subsample size approaches the calculated optimum of 11.1% of the yield-strip sample. Table 5 also gives an indication of the change in the accuracy of estimating a species mean as the size of subsample is changed. For example, in an experiment with four replications, the level of accuracy may be changed from 10.00% to 7.50% by increasing the subsample size from 4% to 19% of the yield-strip sample. It should be pointed out, however, that this reduction in error is limited by the variation between replications. In addition there is a disproportionate increase in total cost as the subsample size is increased.

DISCUSSION

The sampling problem presented in this paper is one example of a number of similar problems often encountered in experimental work. Many other investigations, such as fertility studies, require sampling in the field and subsampling in the laboratory to obtain an estimate of some treatment effect. In studies of this type the variance of a treatment mean and the cost of obtaining the estimate of the mean often take the same mathematical form as those used in this paper. When such is the case the optimum number of subsamples may be determined from the equation [3] given previously. It is advisable, therefore, to conduct the preliminary stages of such an investigation in such a way as to obtain estimates of the variation, σ^2_r, between samples treated alike, the variation, σ^2_s, between subsamples within a sample, and the costs associated with samples, C_r, and subsamples, C_s.

Table 4.—Variance of a species mean, $V_{\bar{x}}$,* total cost, $C_{\bar{x}}$,† and cost per unit of information, C_I,‡ using one replication and varying subsample sizes.

Subsample size (% of sample)	Total cost $C_{\bar{x}}$	Source of Data: Rate of nitrogen experiment, 10% Subsamples		Rate of nitrogen experiment, 20% Subsamples		Management, 10% Subsamples	
		$V_{\bar{x}}$	C_I	$V_{\bar{x}}$	C_I	$V_{\bar{x}}$	C_I
5	$1.75	84.91	149	88.47	155	82.55	144
10	2.00	66.91	134	65.53	131	62.62	125
20	2.50	57.89	145	54.06	135	53.66	135
40	3.50	53.51	187	48.33	169	47.68	167
80	5.50	51.27	282	45.46	250	45.19	249
100	6.50	50.82	330	44.88	292	44.68	290

* $V_{\bar{x}} = \frac{\sigma^2_r}{r} + \frac{\sigma^2_s}{rs}$

† $C_{\bar{x}} = rC_r + rsC_s$

‡ $C_I = (V_{\bar{x}})(C_{\bar{x}})$

Table 5.—Number of replications and size of subsample necessary for given level of accuracy, and total cost, $C_{\bar{x}}$, by each procedure.

Level of accuracy* (as % of the subsample dry weight)	Number of replications	Size of subsample (%)	Total cost $C_{\bar{x}}$
± 5.00	7	Impossible	
	8	50	$34.00
	9	19	22.00
	10	12	21.00
	11	8	21.00
	12	7	22.00
± 6.25	4	Impossible	
	5	72	$25.50
	6	15	13.50
	7	9	13.00
	8	6	14.50
± 7.50	3	Impossible	
	4	19	$10.00
	5	8	9.50
	6	5	10.50
± 8.75	2	Impossible	
	3	17	$ 7.00
	4	6	7.50
	5	4	8.50
±10.00	1	Impossible	
	2	50	$ 8.00
	3	7	5.50
	4	4	7.00

* Confidence probability = 0.95.

If estimates of the variance ratio and of the cost ratio are available from preliminary work or past experience, the optimum number of subsamples in future work may be obtained from table 6.

When it is possible, as it was in this study, to vary the size of subsample, the entries in table 6 may be used as factors for converting from the size of subsample used in obtaining the variance ratio to the optimum subsample size.

Suppose, for example, that the results from a previous experiment indicate that the variation between samples treated

Table 6.—Optimum number of subsamples for different cost and variance ratios.

Cost Ratio $\left(\frac{C_r}{C_s}\right)$	Variance Ratio $\left(\frac{\sigma^2_r}{\sigma^2_s}\right)$				
	0.25	0.50	1.00	2.00	4.00
0.25	1.00	0.71	0.50	0.35	0.25
0.50	1.41	1.00	0.71	0.50	0.35
1.00	2.00	1.01	1.00	0.71	0.50
2.00	2.83	2.00	1.41	1.00	0.71
4.00	4.00	2.83	2.00	1.41	1.00

alike, σ^2_r, is about the same as the variation between subsamples within a sample, σ^2_s, but that the cost associated with each sample, C_r, is approximately four times the cost per subsample, C_s. Then, from table 6, the most efficient subsampling rate in future work is two times the rate used in the previous investigation. That is, in future work twice as many subsamples, or a subsample twice as large, should be taken. It is readily apparent from table 6 that as the relative cost, C_s, associated with the subsample decreases, or the relative variation between samples treated alike, σ^2_r, decreases, the optimum subsampling rate increases.

SUMMARY AND CONCLUSIONS

The botanical composition of two experiments uniformly seeded to white clover, low hop clover, brome grass and orchardgrass was estimated by hand separating subsamples of the fresh forage from the yield-strip sample. The variation between subsamples within plots and the variation between plots treated alike was estimated.

The most efficient size of subsample, $s_{opt.}$, was estimated using the following relationship between costs and variance components:

$$s_{opt.} = \sqrt{\frac{C_r\sigma^2_s}{C_s\sigma^2_r}}$$

With the plot size (5 ft. by 25 ft.) used in this study the most efficient size of subsample for estimating botanical composition by hand separation was found to be approximately 10% of a yield-strip sample 2 feet wide and 23 feet long.

Data are presented showing the size of subsample required to obtain various levels of accuracy with varying numbers of replications when cost is not considered. The estimation of optimum subsampling rate is discussed with respect to experimental procedures in general.

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The Role of Honey Bees in Cotton Pollination[1]

S. E. McGregor, Claude Rhyne, Smith Worley, Jr., and F. E. Todd[2]

MOST cotton breeders recognize the bumble bee *(Bombus* spp.) as one of the most important insects in the cross-pollination of cotton (9), but they also consider the honey bee *(Apis mellifera* L.) as highly important (1, p. 254), (2, p. 117), (3), (6, p. 37), (10), (11). The pollinating activity of honey bees is commonly used to increase the production of seed in such crops as alfalfa and the clovers. This usage of honey bees seems feasible for cotton if beneficial effects of pollination result from bee activity.

Meade (10) showed that thorough hand pollination caused 11% more bolls to set on Durango and 5% more on Acala cotton than did natural pollination. Kearney (5, p. 50) found no difference between natural and hand pollination in either boll set or seed production on Pima cotton in an area where insect pollinators were abundant. In another area where they were scarce, artificial pollination caused a 7.7% increase in the number of matured bolls and 2.9% in the number of seeds per boll, which suggested that a substantially greater crop might be expected if bees were abundant. Meade (10) also suggested that beekeeping might increase cotton yields.

Hybrid vigor, whether defined as an excess production of a hybrid over its better parent or over a standard commercial variety, was shown to exist in Upland cotton by Kime and Tilley (8), Simpson (11), Turner (12), and others. Cook (4), Kearney (6), and Ware (13) also indicated that hybrid vigor exists in hybrids of Upland and

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[2] Entomology Research Branch, A.R.S., U.S.D.A.; Field Crops Research Branch, A.R.S., U.S.D.A.; Arizona Agr. Exp. Sta., and Entomology Research Branch, A.R.S., U.S.D.A., respectively.

Table 1.—Hybrids of cotton detected as a result of bee activity in cages and open plots. Tucson, Ariz., 1952.

Pistillate parent		Percent of hybrids detected in:—		
Gossypium species	Variety	Cages with bees	Cages without bees	Open plots
hirsutum	A-44	2.31	0	0.84
	Red Acala	44.09	2.47*	48.62
	Virescent Yellow Okra Leaf	35.81	0	48.57
	Kime Yellow	26.79	0.80*	38.62
hirsutum/barbadense	Red Acala	30.06	0	—†
	Pima S-1	1.76	0	—
barbadense	Pima S-1	0.62	0	0.71
	Red	—	—	—

* *Melissodes* spp. emerged from the soil and visited flowers before they were discovered and removed.
† Dashes (—) indicate no data taken.

Pima cotton. Worley[3] showed that hand cross-pollination methods are too expensive for obtaining large quantities of seed. The practical use of this potential hybrid vigor in cotton depends, therefore, on the production of more fiber of good quality and, according to Loden and Richmond (9), on the development of methods of economically producing sufficient amounts of seed for the farmer's needs. A possible solution to this seed-production problem, if honey bees are effective, is to concentrate sufficient colonies of honey bees within the field to obtain the adequate cross-pollination.

EXPERIMENTAL PROCEDURE

In 1952 an experiment was conducted to determine the effect of honey bees on the total production of cotton within a variety, and on the production of hybrid seeds. Twenty plots, each containing 60 cotton plants, were located in a field of cotton at Tucson, Ariz. Plastic screen cages, 12 by 24 by 6 feet, were maintained over certain plots throughout the flowering period. Bees were excluded from some of these cages , and a colony of honey bees was placed in others. The colonies contained approximately 20,000 bees each but seldom more than 100 were actively visiting the cotton flowers. The number of colonies per acre necessary to simulate this saturation is presently unknown. These caged plots were compared with similar open plots exposed to chance pollination. Within each *Gossypium hirsutum* plot there were four varieties, including the commercial variety A-44. All other plots contained two varieties, including the commercial variety Pima S-1. A-44 and Pima S-1 were harvested for yield data. The other varieties (see table 1) served as indicators of hybridization between varieties as well as between the two species. Open plots of *G. hirsutum* were surrounded by several rows of A-44 cotton, and open plots of *G. barbadense* by rows of Pima S-1.

[3] Worley, Smith, Jr. Evaluation of an interspecific cotton hybrid (*Gossypium barbadense* X *G. hirsutum*). Master's thesis, University of Arizona, Tucson. 1953.

RESULTS

Plant growth and fruiting were satisfactory within the cages and the caged bees visited the blossoms eagerly. Petals of *G. hirsutum* cotton flowers visited by bees began to turn pink and wither by midafternoon on the day of flowering and would often shed before noon of the following day. In the cages without bees *G. hirsutum* flower petals remained white throughout the day of opening, turned red and withered the second day, and dropped off the third or fourth day. Similar color changes and shedding were observed for Pima cotton.

Pima S-1 cotton in cages exposed to bee pollination yielded 24.5% more seed-cotton than that in cages excluding pollinating insects. This increase in yield was significant and was caused by a highly significant increase in the weight of the bolls, seed and lint, and in the number of seeds per boll (see table 2), and by less shedding of fruit. Weight of lint per individual seed was unaffected by bee activity.

There was no increase in the total yield of A-44 cotton in this experiment, but the bees did cause an earlier crop to set. In the cages with bees, 74.0% of the total crop was harvested at the first picking on Oct. 10, whereas 70.6% was harvested in the cages without bees. These percentages compare with 51.8 vs. 45.7% obtained in other similar experiments on A-33 in 1951, and 64.5 vs. 55.6% on A-44 in 1953. The earlier bolls in the cages with bees, harvested on Sept. 19, were larger—8.20 gm. per boll—as compared with 7.88 gm. in the cages without bees, and with more seeds per boll, 36.2 vs. 34.6. Later in the season, Oct. 30, the trend changed to smaller bolls in the cages

Table 2.—Size of bolls and production of Pima S-1 cotton in cages with and without bees. Tucson, Ariz., 1952.

Treatment	Pounds of lint per acre	Number of seeds per boll	Grams per boll		Grams of lint per 100 seed
			Seed	Lint	
With bees	405	22.7	2.85	1.37	6.0
Without bees	324	20.9	2.65	1.24	6.0
Difference required for significance at 5% level	78.2	0.79	0.08	0.07	—

with bees—6.7 vs. 7.8 gm. per boll, with fewer seeds per boll, 34.0 vs. 39.1. Early production is usually considered desirable.

DISCUSSION AND SUMMARY

The hybrids detected in the different treatments are shown in table 1. Much of the pollen transferred as a result of bee activity doubtless represented visitation between flowers of similar genetic make-up, which was not detectable as cross-pollination. Furthermore, genetic markers are often defective, which might be reflected in the crossing obtained. The amount of crossing obtained in the *G. hirsutum* cages with bees compares favorably with that obtained in the open, an indication that the honey bee can affect cross-pollination in cotton. In the open plots *Melissodes* spp. (Apidae, Hymenoptera) were the predominant pollinators visiting the cotton flowers. There were about 10 times as many flowers of A-44 as of the other genetic markers in the *G. hirsutum* cages and there were still more A-44 flowers in the open. A-44 is a well-adapted commercial variety which produces normal flowers and normal pollen most of the season. The percentage of hybrids obtained reflects these factors.

Kearney and Harrison (7) showed that stigmas of Upland and Pima were highly selective for self pollen. In the *G. hirsutum-G. barbadense* plots with bees, there were approximately equal numbers of Red Acala (Upland) and Pima S-1 flowers. Few hybrids developed from Pima S-1 plants in these cages, but Red Acala plants produced more than 30% of hybrids.

In the *G. barbadense* plots, flowers of the Red variety developed so late that few bolls matured. This late flowering probably accounts for the low percentage of hybrids obtained.

In this experiment honey bees were effective agents in the pollination of cotton. They increased the production of Pima S-1, and caused an earlier crop on A-44 and substantial hybridization between varieties. The inference may be drawn, therefore, that in the open field with ample pollination by honey bees similar results should be expected.

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Effectiveness and Recovery of Initial and Subsequent Fertilizer Applications on Oats and the Succeeding Meadows[1]

George Stanford, John Hanway, and H. R. Meldrum[2]

IN THE midwestern states, it generally has been considered advisable, when fertilizing small grains seeded with legume or legume-grass mixture, to apply adequate fertilizer at time of seeding for both the grain crop and meadow following. An alternative method is to apply a portion of the required fertilizer at time of seeding and top-dress the remainder on the established meadow. Interest in the latter possibility has been stimulated by recent studies which have shown top-dressing to be effective in supplying phosphorus to established meadows (7). However, additional studies are needed to compare the relative effectiveness of single and split applications of phosphorus fertilizers on the new seeding and meadow. Evidence concerning this aspect of phosphorus fertilization is reported in a recent review (7). With respect to potassium fertilization, there seems to be considerable agreement favoring moderate and frequent applications rather than heavy, infrequent applications.

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EXPERIMENTAL PROCEDURE

In the present study, an attempt has been made to evaluate the relative and combined effects of various fertilizer treatments applied initially on oat-legume seedings, and later on the meadow. Specific objectives were *(1)* to study interactions of nitrogen, phosphorus, and potassium fertilizer applications on oats and the succeeding meadow where soils contained low to very low levels of available phosphorus and potassium; *(2)* to evaluate residual effects of initial applications upon the meadow not only as evidenced in yield but also in botanical composition, chemical composition, recovery of applied nutrients, and soil tests for phosphorus and potassium; and *(3)* to study the value of topdressing fertilizers alone or as a supplement to initial applications.

Identical 2 × 2 × 3 NPK factorial experiments were initiated in 1950 at two locations on soils which were low to very low in available phosphorus and potassium. Experiment 1 was on a Carrington fine sandy loam in Buchanan County, Iowa. This soil

Table 1.—Effect of fertilizer treatments on oat yields (bu./A.), 1950.*

Treatment	Experiment 1, Carrington fine sandy loam (pH 5.7; P—very low; K—low)†					
	No N			20 lbs. N		
	No K_2O	40 lbs. K_2O	80 lbs. K_2O	No K_2O	40 lbs. K_2O	80 lbs. K_2O
No P_2O_5	34	39	39	45	47	50
80 lbs. P_2O_5	48	50	54	46	59	68
	Experiment 2, Fayette fine sandy loam (pH 6.1; P—low; K—very low)					
No P_2O_5	46	46	46	42	51	48
80 lbs. P_2O_5	41	42	46	53	66	66

* L.S.D. for treatment at the 5% level of significance: Experiment 1 = 9 bu./A, experiment 2 = 10 bu./A.

† Based on Bray No. 1 test (.025 NHC1 + .03 N NH_4F) for "available" phosphorus and normal NH_4-acetate extraction of exchangeable potassium as interpreted by the Iowa State College soil testing laboratory.

Table 2.—Summary of significant effects exerted by fertilizer treatments on yields and botanical composition as revealed by analysis of variance.

Factor Investigated	Experiment	Significant effects and interactions†
Oat yields	1	N,** P,** K**
	2	N,** P,** K,* N×P**
Hay yields	1	P,** K,** N×K*, P**, (−) p×P.**
	2	N,* K,** N×K,* P,* k,* (−) k×K*.
Botanical composition:		
% red clover	1	(−) N,* K,* P**
% timothy	1	N,* (−) P**

* Significant at the 5% level.
** Significant at the 1% level.
† Capital letters symbolize 1950 treatments; small letters (p,k) refer to 1951 treatments. Negative effects indicated by (−).

had been cropped to corn with only light hill or row fertilizer applications in 1948 and 1949. Prior to 1948, the field had been in non-leguminous pasture for several years without fertilizer or manure application. Experiment 2 was on a Fayette fine sandy loam which had been in a rotation of corn, oats (seeded), and 2 years of alfalfa meadow, with corn grown in 1949. Previous fertilizer applications were rock phosphate at 1000 lbs. per acre on oats in 1946, 8 tons of manure per acre on meadow in 1948, and 100 lbs. 3–12–12 on corn in 1949. Soil test values for both experiments are found in table 1.

On the oat-legume seeding in April 1950, ammonium nitrate, ordinary superphosphate (0–20–0), and muriate of potash to supply 20 lbs. N, 80 lbs. P_2O_5, and 40 lbs. K_2O, or 80 lbs. K_2O were applied in factorial combination arranged in randomized blocks with four replications. Plots were disced after broadcasting fertilizer and seeding to oats and red clover—timothy mixture.

On April 17 of the year following, superphosphate and muriate of potash (40 lbs. P_2O_5 and K_2O per acre) were topdressed on both experiments, using a balanced split-plot factorial design as described by Finney (3).

Hay harvested twice during the season on Experiment 2 consisted largely of red clover. About equal proportions of red clover and timothy with some alfalfa and weeds (less than 10% of the mixture) occurred on Experiment 1. Only one harvest was taken here due to the poor growth which followed the first cutting. Several random hand samples (total of 1 to 2 pounds) were taken from each plot and reserved for botanical separations and for chemical analysis. The methods used in determining total phosphorus and potassium content of the plant materials have been referred to in a previous study (5).

RESULTS AND DISCUSSION

Fertilizer Effects on Yields

Oat yields.—The effects of fertilizers on oat yields are shown in tables 1 and 2. Significant yield increases due to nitrogen, phosphorus and potassium fertilization occurred at both locations. Without exception, the increase from application of a given nutrient was greatest when the other two were supplied. For example, in Experiment 1 there was little response to potassium when either phosphorus or nitrogen were supplied alone, but the yields were 46, 59, and 68 bushels, respectively, with 0, 40, and 80 lbs. K_2O applied in the presence of both nitrogen and phosphorus. The NPK interaction was not significant, however. A somewhat similar result is noted in Experiment 2. Likewise, in Experiment 2 little or no response to phosphorus occurred at the various levels of potassium except where nitrogen also was applied.

Forage yields.—The average yields of forage from each of the 48 fertilizer treatments are recorded in table 3. Average responses to phosphorus and potassium fertilizers applied in 1950 and to phosphorus and potassium top-dressed in 1951 are summarized in table 4.

The residual phosphorus from the initial application resulted in a 0.43-ton increase on Experiment 1. The effect was considerably less on Experiment 2 where a higher level of available soil phosphorus was present. On Experiment 1 top-dressing 40 lbs. P_2O_5 in 1951 increased the yield 0.6 ton per acre where no phosphorus had been applied previously and 0.24 ton where 80 lbs. P_2O_5 had been applied initially. The residual phosphorus from the initial 80-lb. application exerted a smaller effect on yields than did the 40-lb. rate top-dressed on the meadow 1 year later. In view of this, it would appear that more effective use of the 80 lbs. P_2O_5 would have resulted from splitting the application, e.g., one-half at seeding time and the remainder as a top-dressing.

As with phosphorus, the residual effect of potash applied at time of seeding is evidenced in two ways: First, the yields were increased by the initial 40- and 80-lb. applications at both locations, the effects being greater on Experiment 2 where the surface soil contained the least amount of exchangeable potassium. Secondly, on Experiment 2 these initial applications greatly reduced the response obtained from top-dressing 40 lbs. K_2O in 1951. Here the increases due to top-dressing were 0.52, 0.32 and 0.10 ton per acre, respectively, where none, 40, and 80 lbs. K_2O previously had

Table 3.—Yields of hay in relation to time, method, and rate of fertilizer application, 1951.*

Fertilizer top-dressed 1951 lbs/acre	Cuttings	Fertilizer broadcast and disced in before oats, 1950†											
		None	N	P	K_1	NP	NK_1	PK_1	NPK_1	K_2	NK_2	PK_2	NPK_2
		Experiment 1 (Red clover–timothy–alfalfa)											
None	1	1.59	1.52	1.89	1.78	1.93	1.46	1.98	1.79	1.68	1.85	2.11	2.14
p(40 lb. P_2O_5)	1	2.18	1.89	2.35	2.45	2.07	2.26	2.32	2.30	2.13	2.26	2.19	2.29
k (40 lb. K_2O)	1	1.56	1.40	1.97	1.56	2.13	1.83	1.99	2.32	1.53	1.66	2.16	2.20
pk	1	2.21	2.11	2.34	2.32	2.19	2.42	2.60	2.35	2.06	2.39	2.11	2.35
		Experiment 2 (Red clover)											
None	2	2.51	2.43	2.66	2.76	2.45	3.09	2.92	2.86	2.71	2.95	3.10	3.23
p (40 lb. P_2O_5)	2	2.79	2.37	2.88	3.09	2.86	2.81	2.73	3.28	3.14	3.26	3.08	3.29
k (40 lb. K_2O)	2	3.04	3.02	3.14	3.27	3.20	3.24	3.17	3.52	3.09	3.04	3.02	3.37
pk	2	3.26	3.07	3.08	3.18	3.29	3.63	3.25	3.20	3.37	3.41	3.00	3.28

* Significance of treatment effects are indicated in table 2.

† 1950 treatments; N = 20 lbs. N/A; P = 80 lbs. P_2O_5/A; K_1 — 40 lbs. K_2O/A; K_2 = 80 lbs. K_2O/A (broadcast and disced in). 1951 treatments: p = 40 lbs. P_2O_5/A; k = 40 lbs. K_2O/A; pk = 40 lbs. P_2O_6 + 40 lbs. K_2O/A (top-dressed in 1951).

Table 4.—Average effects of initial (1950) and top-dressed (1951) applications on phosphorus and potassium fertilizer on forage yield increases in 1951. (tons per acre.)

Experiment	Residual effects from P_2O_5 or K_2O applied in 1950 at the following rates:		Effect of top-dressing in 1951 of 40 lbs. P_2O_5 or K_2O on plots receiving the following rates in 1950:		
	40 lbs.	80 lbs.	None	40 lbs.	80 lbs.
			Phosphorus		
I	——	0.43**	0.60**	——	0.24**
II	——	0.12*	0.19**	——	0.03
			Potassium		
I	0.12*	0.15**	0.08	0.13	−0.02
II	0.33**	0.48**	0.52**	0.36**	0.10

* Increase significant at 5% level.
** Increase significant at 1% level.

been applied. The 40 lbs. K_2O top-dressed increased yields as much as did the residual from 80 lbs. applied at seeding.

An interaction of nitrogen and potassium occurred in both experiments as shown in table 2. Nitrogen applied at seeding had little effect on hay yields where no potassium had been applied (table 3). However, a generally beneficial effect of nitrogen was noted on plots receiving potassium, especially at the higher rate of potassium application where the average increase calculated from table 3 was approximately 0.2 ton per acre. On Experiment 2 nitrogen significantly depressed yield of hay by approximately 0.2 ton on plots which received no potassium initially. The potassium fertilizer when top-dressed a year later than the nitrogen tended to counteract the adverse effect of nitrogen which occurred in the absence of an initial potassium application, or perhaps merely corrected a deficiency of potassium which was accentuated by nitrogen application. As in Experiment 1, however, nitrogen exerted a significant influence when applied along with potassium at seeding time. Increases

Table 5.—The influence of fertilizer treatments on the relative* and actual amounts of red clover and timothy grown in association (Experiment 1).†

1951 Topdressing	Timothy						Red Clover					
	K_0		K_1		K_2		K_0		K_1		K_2	
	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1
	Percentage of the mixture											
p_0	49	54	43	53	46	46	36	38	47	38	46	44
p_1	41	43	35	44	38	41	48	46	57	45	54	47
	Yield (lbs/acre) of each component											
p_0	1734	1862	1565	1958	1749	1811	1285	1356	1739	1422	1678	1705
p_1	1840	1780	1706	2041	1590	1881	2156	1895	2775	2085	2271	2194

* Expressed as percentage of the total mixture consisting of red clover, timothy, alfalfa and weeds. Average increase or decreases in percentage and pounds of red clover or timothy in the mixture due to fertilizers were as follows:

Treatment	Red clover (%)	Timothy (%)	Red clover (lbs)	Timothy (lbs)
N	−5*	+5*	−415	+383
K_1	+5*	−2	+332	− 14
K_2	+6*	—4	+289	− 46
p	+8**	−8**	+699	− 10

† For interpretation of symbols (N, K, p, etc.), see footnote, Table 3.

from nitrogen on the K_1 and K_2 plots were from 0.15 to 0.2 ton. While the explanation for this nitrogen-potassium relationship is not apparent, the data have called attention to a previously unrecognized beneficial effect of nitrogen in the mixed fertilizer applied to oat-legume seedings.

Botanical Composition

Evaluation of the effects of fertilizer treatments becomes more difficult with a mixture of species than with pure stands, since the various species may show a differential response to treatment. The forage from Experiment 2 was predominantly red clover. The forage from Experiment 1, however, varied widely in the proportion of red clover and timothy, although these two species generally comprised 90% or more of the mixture. The other components (alfalfa and weeds) constituting about 10% of the mixture also were separated and weighed, but are largely disregarded in this paper.

Nitrogen *per se*, did not affect total yields of hay in Experiment 1, although the percentage of red clover was decreased and that of timothy was increased due to nitrogen (table 2). On the other hand, phosphorus applied in 1950 exerted no influence on the relative amounts of red clover and timothy, but greatly increased the total yields of forage. Phosphorus top-dressed in 1951 not only increased yields of the mixture, but also increased the percentage of red clover and decreased the percentage of timothy in the mixture. It is also of interest that potassium applied at seeding increased both yields and percentage of red clover, while neither of these was significantly influenced by top-dressed potassium fertilizer.

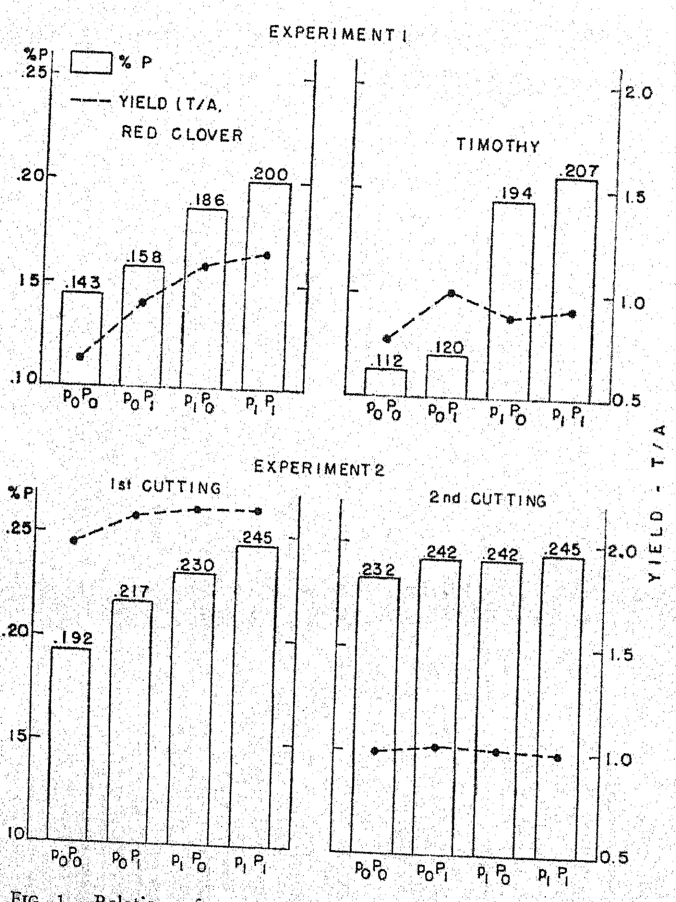

FIG. 1.—Relation of percent phosphorus in forage and yield to phosphorus fertilizer treatment (p_1 = 40 lbs. P_2O_5 applied as topdressing in 1951. P_1 = 80 lbs. P_2O_5 broadcast and disced at seeding in 1950; P_0 and p_0 refer to no phosphorus applied).

The major effects of treatment on botanical composition are summarized in table 5. Here it is evident that fluctuations in the relative amounts of timothy and red clover were largely due to the effects which various treatments exerted on the yields of red clover (see table footnote 1). An exception is the effect of nitrogen, where a decrease in red clover (415 lbs.) accompanied a corresponding increase in weight of timothy (383 lbs.). Neither potassium applied in 1950 nor phosphorus top-dressed in 1951, however, consistently or appreciably affected the average yield of timothy. Thus, increases in red clover yields largely accounted for the residual effect of potassium and the effects of top-dressed phosphorus or potassium fertilizers on *total* hay yields. In contrast to the above, Hanway *et al.* (5) observed with an alfalfa-timothy mixture that the residual effect of superphosphate on hay yields, 1 year following application, could be accounted for solely by the increased yield of timothy. This was explained on the basis that potassium was very deficient, thereby limiting the yield response of alfalfa, but not of timothy, to phosphorus fertilization.

The average amounts of alfalfa and weeds, respectively, found for all plots were 5.1 and 4.3% of the total. The greatest reduction in weed content was exerted by the combined use of phosphorus and potassium fertilizers. Nitrogen increased the percentage of weeds, except where phosphorus or phosphorus and potassium had been applied either at time of seeding or later as a top-dressing.

Uptake of Phosphorus and Potassium by Forage

Percentage composition.—The effect of fertilizer treatments on percentages of phosphorus and potassium in the plants and the relation of plant composition to yield increases obtained from fertilization are of particular interest. Such information offers a means of determining the degree of deficiency or sufficiency of a particular nutrient. The effectiveness of the applied fertilizers often may be evaluated more clearly from a knowledge of nutrient uptake and yield responses, than from either of these criteria considered alone.

It is evident in figure 1 that the phosphorus content of the forages was increased by phosphorus fertilizer. Considering both experiments, it is clear that 40 lbs. of P_2O_5 top-dressed in 1951 increased the phosphorus content more than did the 80-lb. rate of P_2O_5 applied at time of seeding. An exception is the second cutting, Experiment 2, although in this instance plant phosphorus appears to have been adequate even without fertilization.

Of interest is the contrast between red clover and timothy in Experiment 1. Without phosphorus (p_0P_0) and where phosphorus was applied only at seeding (p_0P_1), respectively, the timothy contained 0.112 and 0.120% phosphorus, while the values for red clover were 0.143 and 0.158%. Top-dressing, on the other hand, resulted in equally as high a percentage of phosphorus in the timothy as in the red clover. These increases in percent phosphorus, however, were accompanied by greater increases in yield of red clover than of timothy. There is no positive evidence here that the level of phosphorus required for maximum yield had yet been reached with red clover. On the other hand, it appears that timothy yields did not respond further to increased phosphorus content.

In Experiment 2, increasing the level of plant phosphorus beyond 0.23% gave no further increase in yield with either the first or second cutting. There is evidence, based on results in both experiments, that 0.23% phosphorus represented the approximate "critical" level for red clover.

The relative percentages of potassium in red clover and timothy grown in association are depicted in figure 2. Certain significant trends are shown here. For example, it is evident that phosphorus fertilization reduced the potassium content of red clover, while no effect or increases occurred in the case of timothy. These trends are evident whether or not potassium was applied and regardless of its rate of application. Apparently the grass contained adequate amounts of potassium (perhaps more than was required for maximum yield) at all levels of applied phosphorus. The potassium content of the red clover steadily declined, however, and in various instances where phosphorus was applied, a deficiency level of potassium in the plants is indicated.

The reason for the differential behavior of the red clover and timothy with respect to potassium uptake is not evident from the data. It should be recalled that phosphorus applied in 1950 increased total yields of hay (table 4), but the proportion of timothy and red clover was unaffected. The decline of percentage K in the red clover and relative constancy accompanying this yield response cannot, therefore, be attributed to competition of species induced by increased timothy. Top-dressing of superphosphate also increased total hay yield, but the increase was due solely to response of red clover (table 5). The percentage of potassium in the red clover was decreased as might be anticipated on the basis of increased yield of this species. On the other hand, the timothy showed a significant increase in percent of potassium when phosphorus was top-dressed even though no change occurred in the actual amount of timothy produced. It appears that a competition between species for potassium is involved. The nature of the competition has not been clarified. Evidently, the presence of timothy in the mixture accentuated the problem of potassium supply to the legume when phosphorus was applied in spite of the fact that the proportion of timothy was unaffected or even decreased in some instances by such application. Other evidence relative to competition between associated legumes and grasses for available soil potassium, on soils deficient in this nutrient, has been reported by Blaser and Brady (2), Bear and Wallace (1), Gray *et al.* (4) and Hanway *et al.* (5).

Figure 3 shows the relation between yield of red clover and percent potassium in the plants from Experiment 2. Each of the points on the graph is the average of all nitrogen and phosphorus levels (effectively the mean of 8 replications). In the first cutting samples, the average potassium content ranged between 0.7 and 1.5%. Between these limits, average yields increased approximately 0.5 ton per acre. The value, 1.5%, is regarded tentatively as being near optimum for red clover production. This, however, cannot be deduced from the graph, since it is not clear whether or not the curve has reached a maximum. The potassium content of samples from the second harvest ranged between 0.6 and 1.1%, while yields ranged between 0.8 and 1.1 tons. Potassium deficiency might well have been a factor limiting yields in the second harvest, even with 120 lbs. K_2O per acre applied over a two-year period.

Recovery of applied phosphorus and potassium.—Average amounts of phosphorus and potassium absorbed by the forage and calculated recovery of nutrients applied in 1950 and 1951 are summarized in table 6. Total phosphorus absorption was much less in Experiment 1 than in Experiment 2. From plots receiving no phosphorus (p_oP_o), plants removed 27.7 lbs. of P_2O_5 per acre on Experiment 2 as compared to 8.2 lbs. on Experiment 1, or about 3½ times as much. This difference is explained in part by the fact that two cuttings were obtained from the former while only one cutting was removed from the latter experiment (table 3). After eliminating this factor, however, the total phosphorus absorbed clearly reflects the relative amounts of soluble soil phosphorus (table 1) and relative yield responses from phosphorus fertilization (table 4).

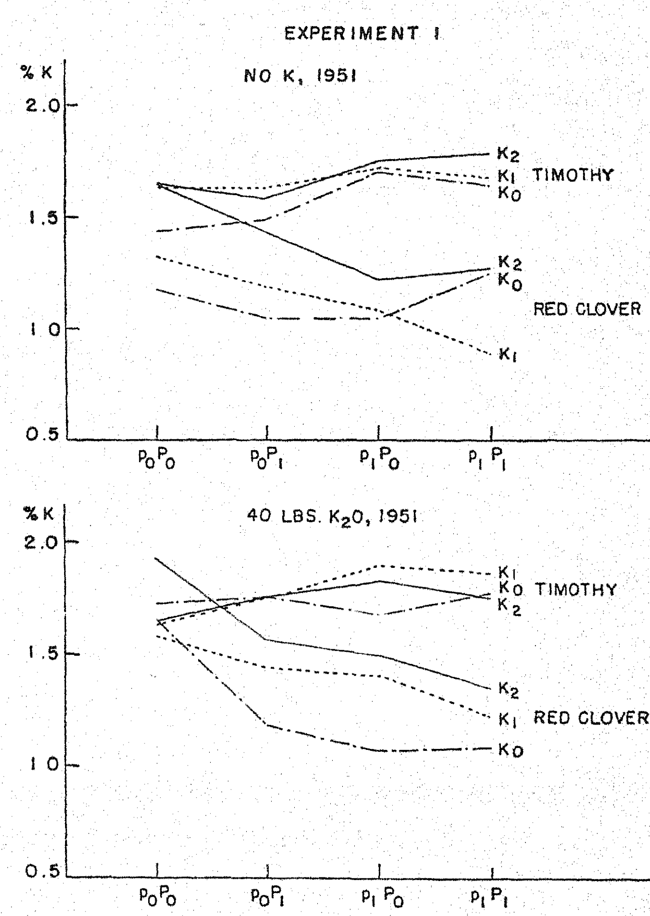

FIG. 2.—Potassium content of red clover and timothy grown in association as related to application of potassium and phosphorus fertilizer (p_1 and P_1 refer to 40 lbs. P_2O_5 topdressed and 80 lbs. P_2O_5 broadcast at seeding respectively. p_o and P_o refer to no phosphorus; K_o, K_1 and K_2 refer to none, 40 and 80 lbs. K_2O applied at seeding).

In both experiments, considerably less phosphorus was recovered from the initial 80-lb. P_2O_5 application (P_1—P_o) than from the 40 lbs. top-dressed in 1951 (p_1—p_o). Recoveries from the 80-lb. application on plots which received no top-dressing were 3.8 and 3.9 lbs. P_2O_5, respectively, on Experiments 1 and 2. As shown in footnote 1, these amounts constitute about 5% of the initial application. In contrast, recoveries from the 40 lbs. P_2O_5 top-dressed on plots receiving no prior phosphorus fertilization were 9.1 and 5.9 pounds per acre, or 22.7 and 14.8%.

Apparently, less phosphorus was recovered from the top-dressed application on plots which received 80 lbs. P_2O_5 at time of seeding than from those which did not receive the initial application. Likewise, the recovery from the 80-lb.

application was reduced by the top-dressing. These findings are in accord with results reported from numerous investigations employing radio-phosphorus.

Recovery of applied potassium fertilizers differed markedly between experiments. Apparent recovery of the 40 lbs. K_2O top-dressed (on K_0 plots) was 16.2% in Experiment 1 and 70% in Experiment 2. Similarly, on Experiment 2 the apparent recoveries of residual potassium from k_0 plots were 17.7 lbs. K_2O for the smaller initial rate (K_1—K_0) and 35.7 lbs. K_2O at the higher rate (K_2—K_0), or 44.3 and 44.6%, respectively. However, only about 12% of the initial 40- and 80-lb. K_2O applications was recovered in the forage harvested from Experiment 1.

Effect of Fertilizer Treatment on Soil Test Values

Soil samples were obtained at both sites from the p_0k_0 and pk subplots of the P_0K_0, P_1K_1 main plots in the fall of 1951. Samples were taken from two replicate plots at depths of 0 to 2, 2 to 4, and 4 to 6 inches and analyzed for soluble phosphorus (Bray No. 1) and exchangeable potassium. Exchangeable potassium values were unaffected by treatment and, therefore, are not presented. Data for soluble phosphorus are presented in table 7. These data show that phosphorus fertilizer application increased the amount of phosphorus soluble in Bray No. 1 extractant in several instances, the effect being most pronounced on the Fayette soil which initially possessed the higher content of soluble phosphorus. This finding is in agreement with data reported by Rich *et al.* (6), for example, who observed that superphosphate brought about a greater increase in soluble phosphorus on plots containing a reserve from prior applications than on an unfertilized plot.

On the Carrington soil, the initial 80-lb. application combined with the top-dressed application effected an increase of 4 lbs. soluble phosphorus in the 0 to 2-inch layer; the composite values for the 0 to 6-inch layer also was significantly increased. The tendency for 80 lbs. P_2O_5 to increase soluble phosphorus at the two lower depth increments, although consistent, was not significant.

On the Fayette soil, phosphorus fertilization consistently increased soluble phosphorus at the three rates of application and three depths of sampling. Significant improvement is shown in the available phosphorus status of the 0 to 6-inch layer, the sampling unit ordinarily employed in soil testing. In this instance, combined applications totaling 120 lbs. P_2O_5 per acre were particularly effective.

It is perhaps significant that effects induced by combined initial and top-dressed applications were generally greater than additive effects of individual applications, in the 0 to 2-inch layer and in the composite 0 to 6-inch layer. This tendency for a positive interaction between initial and top-

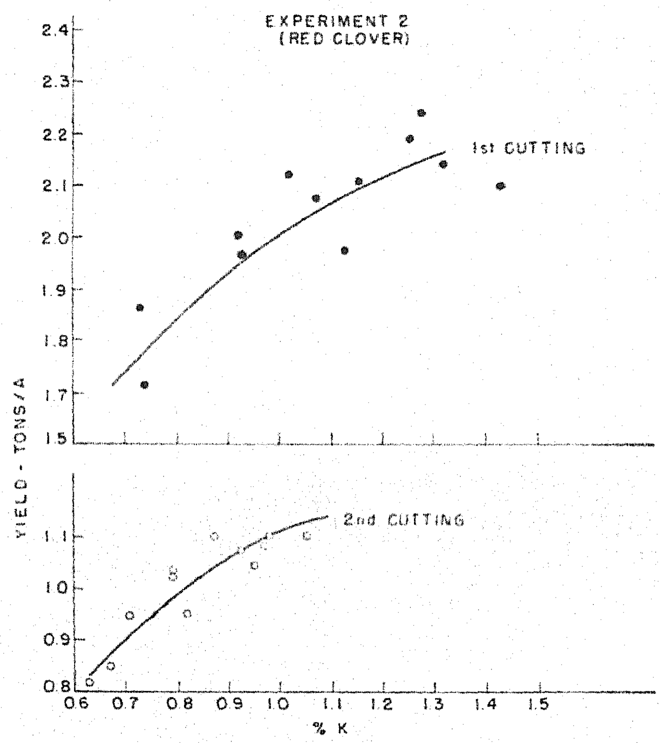

FIG. 3.—Relation between yield and potassium content of red clover, Experiment 2.

Table 6.—Amount of phosphorus and potassium absorbed and apparent recovery from applied fertilizers.*

1951 Topdressing	Phosphorus (lbs. P_2O_5/acre)			Potassium (lbs. K_2O/acre)					
	P_0†	P_1	P_1–P_0		K_0	K_1	K_2	K_1–K_0	K_2–K_0
					Experiment 1				
p_0	8.2	12.0	3.8	k_0	55.8	60.6	65.7	4.8	9.9
p_1	17.3	19.1	1.8	k_1	62.3	74.6	73.3	12.3	11.0
p_1–p_0	9.1	7.1	—	k_1–k_0	6.5	14.0	77.6	—	—
					Experiment 2				
p_0	27.7	31.6	3.9	k_0	44.1	61.8	79.9	17.7	35.7
p_1	33.6	34.9	1.3	k_1	72.1	91.4	95.8	19.3	23.7
p_1–p_0	5.9	313	—	k_1–k_0	28.0	29.6	16.0	—	—

* Calculated percent recovery:

Experiment	% P recovered from		% K recovered from		
	p_1P_0	p_0P_1	k_1K_0	k_0K_1	k_0K_2
1	22.7	4.8	16.2	12.0	12.4
2	14.8	4.9	70.0	44.3	44.6

† For explanation of symbols P_0, P_1, k_0, k, etc. See footnote, table 3.

dressed applications is not unexpected in light of the findings of Rich *et al.* cited above.

SUMMARY AND CONCLUSIONS

In 1950, two 2×2×3 NPK factorial experiments were established on oat-meadow seedings in north-eastern Iowa. Soils were Carrington and Fayette fine sandy loams. On the first year of meadow in 1951, a 2×2 PK factorial was superimposed on each experiment by splitting the main plots. This resulted in 48 distinct fertilizer treatments, the effects of which were evaluated on the basis of hay yields, botanical composition, and chemical composition of the forage. Results presented and discussed in this paper have been confined largely to those which were of major significance. These findings and certain conclusions derived therefrom may be summarized briefly as follows:

1. On both soils, oats responded markedly to nitrogen, phosphorus, and potassium fertilization. Considering meadow yields, however, only potassium appeared to be markedly deficient on the Fayette soil, while phosphorus appeared to be chief limiting factor on the Carrington soil, although in the latter experiment a deficiency of potassium also was evident.

2. A nitrogen-potassium relationship was illustrated in both experiments on the meadow. Neither of these nutrients gave maximum benefits unless the other also was supplied. In fact, a slight depressive effect of nitrogen on hay yields was evident in the absence of potassium fertilizer, whereas significant increases occurred in the presence of additional potassium.

3. In the red clover-timothy association, timothy contained the higher percentage of potassium. With increasing rates of phosphorus fertilizer, the potassium content of red clover declined, while that of timothy remained at the higher level, or slightly increased.

4. On both experiments recovery from top-dressed phosphorus fertilizer was considerably higher than that which occurred from the initial application.

5. Residual effects on the meadow of 80 lbs. P_2O_5 as ordinary superphosphate applied at time of seeding were less than the effects resulting from top-dressing half this amount on the first-year meadow. This was evidenced in various ways: *(a)* a greater yield increase from top-dressing than from residual phosphorus; *(b)* a higher phosphorus content of forage on plots receiving top-dressed phosphorus fertilizer than on those receiving 80 pounds P_2O_5 initially; and *(c)* a higher proportion of the phosphorus in forage derived from the fertilizer on top-dressed plots. The data suggest the need for further investigations to compare the relative benefits derived from single versus periodic application on the oat-legume seeding and the ensuing meadow. Chief concern arises under circumstances where only moderate amounts of phosphorus fertilizer are applied on soils rated low to very low in content of available phosphorus.

6. On the phosphorus-deficient Carrington soil and on the Fayette soil, a general relation occurred between yield response to phosphorus fertilization and percent phosphorus

Table 7.—Effect of initial (1950) and subsequent (1951) applications of superphosphate on soluble phosphorus content of soils at various depths.

Depth of sample (inches)	Soluble P in unfertilized sub-plot (lbs/A)	Increase in soluble P due to:		
		40 lbs. P_2O_5 (1951)	80 lbs. P_2O_5 (1950)	120 lbs. P_2O_5 (1950, 1951)
		Experiment 1 (Carrington)		
0–2	1.5	0.3	1.4	(4.0)*
2–4	1.2	0	0.6	0.7
4–6	1.0	0.2	0.5	1.3
0–6†	1.2	0.1	0.9	(2.0)
		Experiment 2 (Fayette)		
0–2	3.8	(4.0)	(3.3)	(8.9)
2–4	3.5	0.7	1.6	1.8
4–6	2.5	1.5	1.4	(3.0)
0–6†	3.3	(2.0)	(2.0)	(4.3)

* Values in parenthesis were at least three times as large as the appropriate standard error for comparison of no treatment means with indicated phosphorus treatment mean, and are, therefore, regarded as being significantly greater than values for no treatment.
† Average of preceding values.

in the plants. In these experiments, 0.23% phosphorus appeared to be a near optimum level for red clover at full bloom.

7. On the potassium-deficient Fayette soil, yields for a particular cutting of red clover were clearly related to percent potassium in the plants. A marked deficiency apparently existed at second cutting even where 120 lbs. K_2O previously had been applied.

8. Soil tests at the end of the first hay year (1951) revealed significant carry-over of phosphorus soluble in Bray No. 1 reagent from both initial and top-dressed applications of superphosphate. There was, however, little evidence of residual exchangeable potassium due to previous applications.

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Absorption of 2,4-Dichlorophenoxyacetic Acid by Soybean and Corn Plants[1]

Ellis W. Hauser[2]

THE unusual success of 2,4-dichlorophenoxyacetic acid (2,4-D) as a herbicide is due largely to its differential toxicity for a variety of plants. Although this chemical is the most extensively studied herbicide, the mechanism of its herbicidal action remains relatively obscure. Physiologically, the toxic effects of 2,4-D may be divided into three phases: *(a)* absorption, *(b)* translocation, and *(c)* toxic action. In order to be inhibitory, 2,4-D must first be absorbed by plant organs. The primary purpose of this study was to evaluate various factors influencing the absorption of 2,4-D compounds.

REVIEW OF LITERATURE

Weaver and DeRose (17) and Rice (13) found that maximum amounts of 2,4-D were absorbed by leaves of soybeans within a few hours after treatment. Crafts (3) theorized that esters of 2,4-D are more easily absorbed by the foliar plant parts due to solubility in the plant cuticle. On the other hand, the polar salts would enter roots more readily. Beevers *et al.* (1), using a malonate inhibition system, obtained evidence that undissociated ester molecules penetrated cells more rapidly than free acid molecules. Another factor influencing toxicity of 2,4-D is pH. Hammer *et al.* (5) found that 2,4-D solutions were more toxic at low pH's.

Numerous investigators have shown that the addition of chemically unrelated activants increases the toxicity of 2,4-D (4, 7, 12, 13, 15, 17). Hitchcock and Zimmerman (7) believed that adjuvants alter permeability of plant tissues and hasten penetration of the chemical. Rice (13) found that absorption of 2,4-D from solutions containing Carbowax took place over longer periods of time than from wholly aqueous solutions, and that more chemical was absorbed from solutions activated with wetting agents. According to Mitchell and Linder (12) addition of wetting agents increased absorption of radioactive 2,4-D from 3 to 350%. The addition of Dreft, a commercial detergent, increased toxicity of sodium 2,4-D to corn plants, according to Rossman and Staniforth (15). Staniforth and Loomis (16) showed that decreased surface tension and increased absorption of 2,4-D from solutions containing wetting agents are probable reasons for increased toxicity, but state that the relationships are complex.

Several investigators have found a positive correlation between the presence of leaf carbohydrates and the toxic action of 2,4-D (11, 14). Hauser and Young (6) found that leaf carbohydrates were necessary for translocation but not for absorption of 2,4-D.

Temperature is an important environmental factor affecting the toxic action of 2,4-D. Several investigations have shown that plants are more susceptible at higher temperatures (8, 10). One explanation seems to be that more chemical is absorbed as the temperature is increased (2).

EXPERIMENTAL METHODS

The plant material for the various greenhouse experiments consisted of young soybeans *(Glycine max* (L.) Merr.) and corn *(Zea mays* L.) plants. These plants were selected because soybeans are readily susceptible to 2,4-D injury while corn possesses moderate resistance. Soybean seedlings of the variety Hawkeye or Lincoln were grown in 4-inch pots and thinned to 3 per pot several days before treatment. The corn seedlings also were thinned to 2 or 3 plants per 4-inch pot.

Spray applications were made with a converted DeVilbiss paint gun operating under a constant pressure of 20 psi. The potted plants were placed in a spray chamber on a revolving turn-table and 10 ml. of spray solution from a beaker was applied evenly through the paint gun. The sprayer was adjusted so that successive applications were made at the same distance from the plant material. In a few experiments, the plants were dipped into the spray solutions to be tested.

To measure absorption effects, the soybeans were treated when the primary leaves were expanded and the first trifoliate leaves were still in the bud stage. The buds weighed approximately 0.1 gm. per pot. A pot of 2 or 3 plants was the experimental unit and uniform units were grouped into 3 to 8 replicates. Randomized block or split plot designs were used. The plants were sprayed, and then after specified periods of time were washed thoroughly in a series of four water-Dreft solutions and finally in tap water to remove the unabsorbed 2,4-D residues. The toxicity of 2,4-D was evaluated by weighing all of the new growth above the primary leaves of soybean plants 10 to 14 days after treatment. The absorption which occurred was assumed to be inversely proportional to the weight of new growth. The method of treatment used in the corn studies was the same as for beans. The height of each seedling was measured at the time of treatment and 10 to 14 days later. The seedlings averaged 6 to 8 inches in height on the date of treatment. Reductions in the height of treated plants were assumed to be proportional to the amount of absorbed chemical.

The following technical 2,4-D compounds were used: *(a)* sodium salt, *(b)* monoethylamine, and *(c)* dioctylamine. In addition, treatments were made with 2,4-D dimethylamine salt and isopropyl ester formulations. The surface active agents used were: *(a)* Tergitol 7 (anionic), *(b)* Triton B-1956 (nonionic), *(c)* Hyamine 2389 (cationic), and *(d)* C-61 (cationic). Hyamine 2389 was slightly toxic to soybean plants; the other wetting agents *per se* did not produce significant injury at the concentrations and exposure intervals used.

To evaluate the possible effect of differential spray retention on the data obtained, a total of 30 measurements were made to determine the amount of spray retained by soybean plants receiving totally aqueous solutions as opposed to solutions containing 0.5% Tergitol 7, the most effective spreader used. For each measurement, 3 excised plants were inserted into a drilled wooden block (simulating a pot), placed on the revolving turntable and sprayed with 10 ml. of solution. Fifteen measurements were made for each type of solution. The plants were weighed before and immediately after spraying to determine the amount of solution applied. Averages of these measurements showed that 0.18 gm. of wholly aqueous solution and 0.21 gm. of solution containing Tergitol 7 was retained per set of three plants.

RESULTS

The influence of wetting agents on the absorption of sodium 2,4-D (100 ppm.) by soybeans was determined in preliminary experiments. Exposure intervals of 7, 15, 30, and 60 minutes were used. In addition, one series of plants was treated with sodium 2,4-D but not washed. This compound in wholly aqueous solutions did not enter in quantities sufficient to reduce new growth during a 60-minute exposure, but when surface active agents were added, significant absorption occurred in 30 minutes. Yield reductions were greater with a 60 minute exposure to 2,4-D sprays containing a wetting agent than for unwashed plants sprayed with 2,4-D; those plants which were not washed were exposed to the chemical for the duration of the experiment. When the concentration was increased ten times (table 1) sodium 2,4-D without adjuvants was not absorbed sufficiently

[1] Journal paper No. J-2487, of the Iowa Agr. Exp. Station, Ames, Iowa, Project 944. Additional data and the details of the experiments are contained in the author's doctoral dissertation in the Iowa State College Library, Ames, Iowa. Rec. for publication Aug. 6, 1954.

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Table 1.—New growth of soybeans sprayed with sodium 2,4-D, 1,000 ppm., with and without surface active agents (0.5%).

Treatment	Average weight of new growth*			
	Exposure interval			Treat. means
	4 min.	7 min.	15 min.	
	grams	grams	grams	grams
Sodium 2,4-D plus Hyamine 2389	0.67	0.38	0.05	0.37
Sodium 2,4-D plus Tergitol 7	1.24	0.35	0.25	0.61
Sodium 2,4-D	2.49	1.81	2.09	2.13
Sodium 2,4-D, not washed	0.04	0.02	0.00	0.02
Untreated check	2.16	1.92	2.02	2.03
Interval means	1.32	0.90	0.88	——

L. S. D.'s: Treatment means—(0.05) = 0.20 gm. (0.01) = 0.27 gm. Interval means (0.05) = 0.21 gm. (0.01) = 0.30 gm.

* Each figure is the average of 5 replicates.

Table 2.—New growth of soybeans sprayed with the isopropyl ester of 2,4-D, 50 ppm., with and without surface active agents (0.5%).

Treatment	Green weight of new growth*				
	Exposure interval				Treat. means
	7 min.	15 min.	30 min.	60 min.	
	grams	grams	grams	grams	grams
Isopropyl ester 2,4-D plus B-1956	2.14	1.32	0.94	0.56	1.24
Isopropyl ester 2,4-D plus C-61	2.31	2.47	1.97	1.68	2.11
Isopropyl ester 2,4-D plus Tergitol	0.93	0.40	0.43	0.74	0.62
Isopropyl ester 2,4-D	1.73	1.90	0.99	1.03	1.42
Isopropyl ester 2,4-D, not washed	1.39	0.85	1.17	1.18	1.15
Check	3.29	3.85	3.85	3.51	3.63
Interval means	1.97	1.80	1.56	1.45	——

L. S. D.'s: Treatment means—(0.05) = 0.24 gm. (0.01) = 0.32 gm. Interval means (0.06) = 0.25 gm. (0.01) = 0.35 gm.

* Each figure is the average of 6 replicates.

to injure the plants during a 15-minute exposure, but when wetting agents were added to the spray solutions, significant absorption occurred within 4 minutes. Application of the sodium salt at a concentration of 500 ppm. resulted in similar trends (figure 1A).

Addition of surface active agents to solutions of 75 ppm. of the dimethylamine form of 2,4-D reduced the time required for absorption during exposure intervals of 7, 15, 30, and 60 minutes. When the concentration was increased to 750 ppm., exposures of 4 minutes with and 7 minutes without adjuvants were required for absorption of toxic quantities (figure 1B). A comparison of plants treated with the amine and sodium salt of 2,4-D for short exposure periods is shown in figure 1C.

The absorption rates of the ester were strikingly different from the sodium and amine compounds (tables 2 and 3). The data show that the isopropyl ester entered rapidly, yet the addition of surface active agents, with the exception of C-61, further speeded the entrance of the chemcial into plant tissues. The plants in the 0-exposure series (table 3) were washed immediately after the spraying process, which lasted approximately 1 minute. Apparently, absorption of the ester began immediately after application and was very rapid during the first few minutes. Other experiments using higher concentrations of the isopropyl ester of 2,4-D gave essentially the same results.

Table 3.—New growth of soybeans sprayed with the isopropyl ester of 2,4-D, 100 ppm., with and without Tergitol 7(0.5%).

Exposure interval	Green weight of new growth*		Check
	2,4-D	2,4-D plus Tergitol 7	
	grams	grams	grams
0 min.	1.38	1.36	1.71
1 min.	1.22	0.95	——
2 min.	1.09	0.80	——
4 min.	0.94	0.51	——
Not washed	0.63	0.29	1.71

L.S.D.'s: Treatment—(0.05) = 0.35 gm. (0.01) = 0.47 gms.

* Each figure is the average of four replicates.

The growth responses of corn, a moderately resistant plant, were similar to those of soybeans. The three 2,4-D compounds previously used were sprayed on corn plants at a concentration of 1,000 ppm. The exposure intervals were 0, 15, 30, and 60 minutes. In addition, other treated plants were unwashed and exposed for the duration of the experiment. Sodium 2,4-D was absorbed only slightly, even when the plants were not washed; however, when surface activants were added to the solutions, significant height reductions

resulted from a 60-minute exposure. Absorption of the amine salt occurred in 60 minutes, but if adjuvants were added, sufficient absorption took place in 15 to 30 minutes after treatment to cause significant growth reductions. The isopropyl ester was absorbed by corn within a few minutes after treatment, but the addition of adjuvants further reduced the growth.

The effect of the leaf carbohydrate supply on absorption of 2,4-D was studied by dipping soybean plants previously held in darkness for 48 hours into 2,4-D solutions and then washing the 2,4-D from the plants after specified exposure periods. A comparison of treated plants is shown in figure 1 (D). Reserve carbohydrates were apparently not a critical factor affecting the absorption of 2,4-D.

Concentrations of sodium 2,4-D ranging from 1,000 to 10,000 ppm. were used to evaluate the effect of concentration on absorption by soybeans and corn. The rate of effective absorption was more rapid as the concentration, and consequently the quantity of 2,4-D applied, was increased.

Temperature is an important environmental factor affecting the action of 2,4-D compounds. Soybean plants were exposed to different temperatures 2 hours before and 30 minutes after dipping into 2,4-D solutions. After the 30-minute exposure, the plants were washed and returned to the greenhouse bench. As the temperature was increased during exposure, more 2,4-D was absorbed (table 4). A particularly severe reaction occurred at 61° F. Further research is needed to clarify this relationship which was observed consistently in these studies.

To test the effect of soil moisture on the absorption of 2,4-D, some soybean plants were grown with soil moisture held near the field capacity and others were watered only after the plants were temporarily wilted but had not reached the permanent wilting point. Both series of plants were sprayed with 250 ppm. of amine 2,4-D plus 0.5% Tergitol 7. The data showed that greater absorption occurred where the plants had been supplied with adequate water.

The toxic action of 2,4-D and other herbicides may be greatly affected by the pH of the spray solutions. Several experiments were conducted to evaluate the effect of pH on the absorption of 2,4-D compounds. Buffered solutions at pH values of 5, 7, and 9 were sprayed on soybeans. The sodium and amine forms were most toxic at pH values of 5 and 7 and least toxic at pH 9.

DISCUSSION

Previous investigations designed to separate absorption of 2,4-D from translocation have not been extensive, although these two processes may not be closely related. By use of the methods described, an attempt has been made to evaluate the effect of several factors influencing absorption of 2,4-D compounds.

Although the spraying method used in most of these experiments did not permit quantitative separation of absorption from translocation, it was assumed that growth responses would be inversely proportional to quantities of chemical absorbed during given exposure periods. Although differential spray retention also contributed to the differences observed, retention data indicated that this factor alone could account for only a portion of the observed differences.

The type of 2,4-D compound markedly influenced the rapidity of absorption. The isopropyl ester was absorbed most rapidly, an amine salt was intermediate, while the sodium salt was absorbed slowly. This agrees with Craft's theory (3) that growth regulants of a non-polar nature should be absorbed by the cuticle more readily than polar molecules. It was noted that surface active agents reduced the differential toxicities of 2,4-D compounds. This may be accomplished, in part, by reductions in surface or interfacial tension, which bring the polar salts of 2,4-D into more intimate contact with the leaf surface.

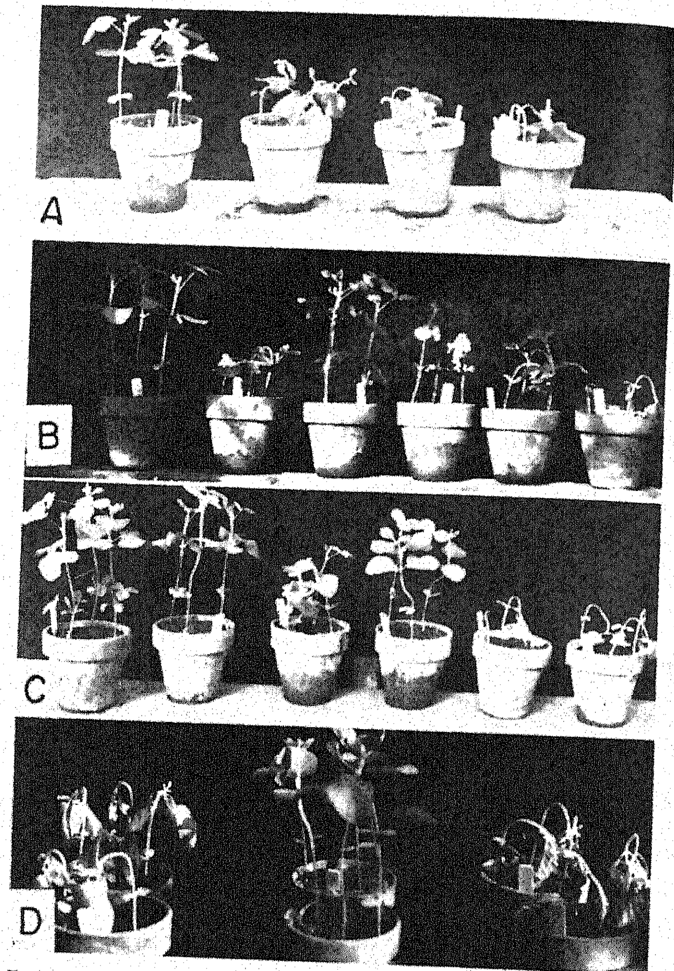

FIG. 1.—Soybeans photographed 10 days after treatment with different 2,4-D compounds for indicated exposure periods.

(A) Sodium salt at 500 ppm. Left to right: Pot 1—untreated check; Pot 2—no surface activant, exposed 2 hours; Pot 3—with surface activant, exposed 30 min.; Pot 4—no surface activant, exposed for duration of experiment.

(B) Amine salt at 750 ppm. Left to right: Pot 1—untreated check; Pot 2—with surface activant, exposed 4 min.; Pot 3—no surface activant, exposed 4 min.; Pot 4—with surface activant, exposed 15 min. Pot 5—no surface activant, exposed 15 min.; Pot 6—no surface activant, exposed for duration of experiment.

(C) Amine 750 ppm. and sodium 1,000 ppm. no surface activant used. Left to right: Pot 1—amine, exposed 4 min.; Pot 2—sodium salt, exposed 4 min.; Pot 3—amine, exposed 15 min.; Pot 4—sodium salt, exposed 15 min.; Pot 5—amine, exposed for duration of experiment; Pot 6—sodium salt, exposed for duration of experiment.

(D) Effect of leaf carbohydrates on absorption of amine, 500 ppm. Left to right: Pot 1—light before and after treatment, washed 24 hours after treatment; Pot 2—48 hours darkness before, washed immediately after treatment; Pot 3—48 hours darkness before and 24 hours after treatment, washed at end of dark period.

The data presented here and those from other sources (2, 4, 6, 7, 12, 15, 17) demonstrate that the addition of

Table 4.—New growth of soybeans after 30 min. exposure at different temperatures to sodium 2,4-D, 750 ppm. plus 0.5% Triton B-1956.

Exposure temperature F°	Replicate								Means for tempera-ture
	1	2	3	4	5	6	7	8	
	grams	grams	grams	grams	grams	grams	grams	grams	grams
37	3.23	2.52	4.03	3.02	3.50	4.66	3.72	4.67	3.67
50	1.73	1.47	3.50	2.88	3.80	3.13	3.76	3.03	2.91
61	0.93	1.23	2.12	1.15	0.93	1.59	1.87	1.68	1.44
68	0.57	1.11	2.57	2.50	2.53	3.00	2.35	1.80	2.05
81	0.65	0.25	1.33	1.03	0.40	1.33	0.72	0.80	0.81
Check	3.94	3.97	4.00	5.66	4.53	4.63	4.98	4.55	4.53

L. S. D.'s: (0.05) = 0.55 gm.
Treatments (0.01) = 0.74 gm.

surface active agents increases the absorption and overall toxicity of 2,4-D compounds. Most surface active agents decrease surface tension and lower the contact angle, thus promoting more intimate contact of the spray solution with plant surfaces. However, Staniforth and Loomis (16) have shown that only a portion of the activation can be accounted for by surface tension measurements. In addition to the ease of wetting and differential retention, other factors may be involved.

Several investigators (6, 11, 14) have shown that translocation of 2,4-D is dependent upon the presence of the leaf carbohydrates associated with normal transport. Our data indicate that absorption processes are not dependent upon the presence of carbohydrates in the leaves of bean plants, suggesting that the processes of absorption and translocation are governed, at least partially, by different factors.

Previous investigations have shown that plants are more susceptible to 2,4-D at higher temperatures (8, 10). The data presented here agree with those of Bryan, *et al.* (2) and indicate that increased absorption is a contributing factor to the greater susceptibility observed at higher temperatures.

Less 2,4-D was absorbed by plants grown under moisture stress than by normal plants. According to Loomis (9) drought conditions are conducive to development of "differentiation processes" in the plant: growth is reduced, sugars accumulate, and the cuticle is thickened. It seems probable that the changes in the cuticle, in particular, contribute to reduced absorption under these conditions. A lowered general physiological activity could be contributory, also, by reducing plant responses.

The pH of the spray solutions influenced absorption and final toxicity of 2,4-D solutions. Both the sodium and amine forms entered the plants more readily from solutions of pH 5 and 7 than of pH 9. There were no significant differences between pH 5 and 7. The results obtained do not agree entirely with those of Hammer *et al.* (5) who found progressive increases in toxicity of the sodium salt with lowered pH ranging down to 2.5. The mechanism of the interaction between 2,4-D toxicity and pH was not established.

SUMMARY

The absorption of 2,4-D compounds was studied by exposure of soybean or corn plants to the chemicals, and then washing the residues from the plant surfaces after specified periods of time. Growth responses subsequent to treatment were the criteria used for evaluating the amount of 2,4-D which entered the plants.

The principal results of these investigations may be enumerated as follows:

1. The isopropyl ester of 2,4-D was absorbed by soybean and corn plants rapidly, the sodium salt was absorbed slowly, while the amine was intermediate in rate. Addition of surface active agents to the spray solutions increased the rates of absorption of all the 2,4-D compounds.
2. The differential toxicities of the 2,4-D compounds were decreased by surface activants.
3. The rate of absorption was positively correlated with the exposure period.
4. A reserve carbohydrate supply in soybean leaves was not essential for the absorption of 2,4-D.
5. The rate of absorption was more rapid as the concentration of 2,4-D per unit volume of solution was increased.
6. Plants grown with decreased soil moisture absorbed 2,4-D more slowly than plants supplied with adequate water.
7. The sodium and amine forms of 2,4-D were less toxic at pH 9 than at pH of 5 and 7.

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High Altitude Meadows in Colorado: I. Effect of Irrigation on Hay Yield and Quality[1]

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THE high altitude meadows of the 11 western states comprise approximately 3,800,000 acres with an average production of about 1.1 tons of hay per acre (7). Colorado has 550 to 600 thousand acres of high altitude meadows. They are used for the production of hay and for pasture and are an important part of the irrigated lands of the West.

Livestock graze the meadows in the spring and fall. While the animals are on summer pasture, the meadows produce a crop of hay that is used as winter feed. This "one crop" system, in use for many years, is the common practice in most of the high altitude meadow areas.

These high altitude areas have short growing seasons, low mean temperatures and high light intensities. The soil mantle is often shallow with so much organic matter incorporated in the top few inches as to form a mat. This soil mantle is usually underlain by sand, gravel and cobble at depths varying from a few inches to several feet below the surface.

Colorado ranchers state that the yields of hay from their high altitude meadows have been declining for a period of years. This decline may have resulted from several factors such as the following:

(1) Irrigation practices have been followed which involve excessive use of water. This has resulted in the development of a low yielding vegetation which includes a large population of sedges (*Carex* spp.) and rushes (*Juncus* spp.).

(2) Continuous cropping of hay has been practiced. This, combined with excessive irrigation, apparently has resulted in soils that have a thick sod cover and low levels of available nutrients, especially nitrogen.

In addition, much of the hay has been harvested at advanced stages of maturity. Work conducted on the high altitude meadow areas of Nevada (6) has shown that late harvesting results in decreased nutritive value of the hay. It is probable that maturity has the same effect on forage in Colorado.

From 1950 through 1953 an experiment was conducted to investigate the effects of improved irrigation practices, application of commercial fertilizers, seeding legumes into the meadows, and improved harvest management practices, in relation to the yield and quality of hay. This paper deals primarily with the effects of various irrigation practices.

MATERIALS AND METHODS

A high-altitude meadow near Gunnison, Colo., at an elevation of 7,460 feet, was chosen as the site for this study. The mean annual precipitation is approximately 10 inches with about 5 inches occurring during the 4-month growing season (3). The meadow is usually covered with snow from mid-November through March. Sub-freezing temperatures may be expected at any time, and have occurred at least once in 47 of the 48 months of this study. Temperature variations of 50° F. within an 8-hour period are common during the growing season. Maximum air temperatures rarely exceed 82° F. Minimum temperatures for the 3 winter months average approximately —6.5° F. (5).

The experimental area is fairly representative of much of the better-drained high-altitude meadow land in Colorado. It is subject to a high water table during the irrigation season. The soil is a loam, ranging in depth from 1 to more than 60 inches, and is underlain with a sand-gravel-cobble substratum typical of many Colorado high-altitude meadows.

At the outset of the experiment the vegetation was a mixture of smooth brome grass (*Bromus inermis* Leyss), bluegrasses (*Poa* spp.), and alsike clover (*Trifolium hybridum* L.) with small amounts of timothy (*Phleum pratense* L.), sedges (*Carex* spp.) and rushes (*Juncus* spp.).

A split-plot experiment was designed consisting of four irrigation practices (plots 60 by 120 feet), two sod management or seeding practices (plots 60 by 50 feet), eight fertility treatments (plots 14 by 25 feet), and two harvest management practices (plots 7 by 25 feet) in factorial combination and randomized in each of four replications.

In 1950 and 1951 the four irrigation practices investigated were: three variations of flood irrigation—continuous, intermittent at short interval and intermittent at long interval; and sprinkler irrigation, intermittent at long interval. The short-interval and long-interval plots were irrigated when soil moisture tension at a 6-inch soil depth reached 300 cm. and 600 cm. of water, respectively, as determined by tensiometers. In 1952 and 1953 the long-interval plots were irrigated when the soil moisture tension at a 6-inch depth reached 5 atmospheres as determined by use of Bouyoucos blocks.[3] The change to a higher moisture tension was made because using tensions of 300 and 600 cm. of water did not give the desired differences in irrigation requirements. The soil moisture

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[3] Laboratory tests showed that a resistance of 9,000 ohms in the Bouyoucos blocks indicated a soil moisture tension of 5 atm.

level at a 6-inch depth under the short interval irrigation practices was maintained at or about 32%, which had been found to approximate the field capacity for this soil. Irrigating at a tension of 5 atmospheres permitted the soil moisture level to drop to about 21% before irrigation. This drop represents a utilization of 85% of available soil moisture at the 6-inch depth between irrigations, based on a soil moisture level at 15 atmospheres (permanent wilting point) of approximately 19%. The water applied to the flood irrigated plots was measured on and off each plot over sharp crested weirs equipped with water level recorders. The amount of water applied by sprinkler irrigation was measured in cans.

Sod management studies consisted of a comparison between the native sod and the native sod seeded to a mixture of mammoth red clover, alsike clover, and birdsfoot trefoil. The seed was applied broadcast.

The eight fertility levels studied included a non-treated check—nitrogen at rates of 40, 80, and 160 pounds per acre, applied as ammonium nitrate; phosphorus at a rate of 200 pounds P_2O_5 per acre, applied as treble superphosphate; and applications of 100, 200, and 400 pounds of P_2O_5 per acre in combination with a constant rate of 160 pounds of nitrogen per acre. Nitrogen applications were repeated annually and were broadcast on the surface, with the exception of the first application, which was drilled at a depth of approximately 3 inches. Phosphorus was applied only in 1950 at a depth of 3 inches.

Harvest management was studied by comparing the results obtained from an early harvest with those from a late harvest. The early harvest method consisted of harvesting in early July followed by harvesting the aftermath in late August. The late harvest consisted of a single cutting in late August.

Visual estimations of the percentage of total ground cover attributable to each species were made prior to the early harvest each year, with the exception of 1950.[1]

In addition to yields of hay, the effects of the above practices on percentages of crude protein and total phosphorus, and yields of crude protein per acre and total phosphorus uptake per acre were studied. Under the practices commonly employed in the mountain meadow areas such as excessive irrigation, harvesting at advanced stages of maturity and no fertilization, the crude protein and phosphorus percentages frequently fall below minimum values regarded as essential for wintering of livestock (4).

The Kjeldahl method designed to recover only organic nitrogen was used to determine crude protein percentages. In the total phosphorus analyses, the digestion mixture described by Bolin and Stamberg (2) was used. The concentration of phosphorus in the digestate was determined colorimetrically by the phosphovanadomolybdate method as modified by Barton (1).

All data presented are based on hay oven-dried at 70° C.

[1] Species estimations were made by Bruno Klinger, Department of Botany, Colorado A & M College; K. G. Brown and Dr. A. D. Dotzenko, Colorado Agr. Exp. Sta.

RESULTS AND DISCUSSION

Comparison of Continuous and Intermittent Irrigation Practices

In the first year, 1950, the ranchers' methods of irrigation were supplanted by the experimental methods. During this transition year, there were no significant differences among the various irrigation treatments in any of the variables studied, namely, hay yields, percent and yield of crude protein and percent and removal of phosphorus. Even though the continuous irrigation practices were used only during the latter part of the growing season in 1950, more than 100 acre-inches of water were applied to produce 1 ton of hay as compared with 5 acre-inches under intermittent (sprinkler) irrigation.

In 1951 all irrigation practices were under control. The intermittent irrigations did not yield significantly more hay than continuous irrigation, except in the aftermath. However, in the quality factors, intermittent irrigation gave much better results than continuous irrigation in all harvests. Table 1 summarizes the data showing the superiority of intermittent sprinkler irrigation over continuous irrigation. Applications totaling 136 acre-inches of water were required to produce 1 ton of hay by continuous irrigation compared with 1.2 acre-inches per ton with the intermittent irrigation. This water requirement for intermittent irrigation is unusually low, and probably is due to a high water table in the area which may have supplied a portion of the required water in 1951. The 4-year average requirement was 2.9 acre-inches per ton.

Continuous irrigation was not studied after 1951.

Comparison of Sprinkler with Flood Irrigation Practices

During the 4 years, 1950 to 1953, sprinkler and flood irrigation practices have been compared using the same criteria for irrigation, namely, a soil moisture tension of 300 cm. of water at a 6-inch depth. There have been no significant differences in hay yields or quality between the hays produced under the two practices.

With respect to the amount of water used, sprinkler irrigation was more economical than flood irrigation. During 1952, for example, under sprinkler irrigation, 2.5 acre-inches

Table 1.—Yield of hay, percent and yield of crude protein, percent and removal of phosphorus, as affected by continuous and intermittent* irrigation and harvest management, 1951. (means of sod management and fertilizer treatments).

	Irrigation Practice					
	Continuous	Intermittent	L.S.D. (0.05)	Continuous	Intermittent	L.S.D. (0.05)
	Early cutting			Aftermath cutting		
Tons hay/acre†	2.37	2.58	N.S.	0.47	1.12	0.13
Percent crude protein†	9.8	13.3	1.9	13.3	16.1	2.9
Pounds crude protein/acre†	464	678	153	123	359	64
Percent total phosphorus†‡	.217	.258	N.S.	.220	.285	.052
Phosphorus removal†	10.32	13.15	2.76	2.21	6.05	1.65
	Early plus aftermath			Late harvest		
Tons hay/acre†	2.84	3.69	N.S.	3.04	3.41	N.S.
Percent crude protein†	—	—	—	7.6	9.4	1.3
Pounds crude protein/acre†	587	1,036	238	451	629	122
Percent total phosphorus†‡	—	—	—	.157	.175	N.S.
Phosphorus removal†	12.53	19.20	3.60	9.62	11.45	1.75

* Sprinkler irrigation method.
† Data are based on hay oven-dried at 70° C.
‡ Means of native sod only.

of water were applied for each ton of hay produced compared to 8.2 acre-inches per ton with flood irrigation.

Some consideration should be given to the fact that this experiment was conducted on a relatively smooth meadow with a fairly uniform slope. This made possible the control of flood irrigation water with greater precision and efficiency than would be possible on a rougher, less uniform area. It is suggested that with the latter conditions, the uniformity and efficiency of distribution by sprinkling methods might result in significant improvement in yield and quality of hay over flood irrigation.

Comparison of Flood Irrigation at Different Soil Moisture Tensions

During 2 years, 1952 and 1953, direct comparisons have been made with respect to hay yields between one flood irrigation practice which provided for irrigation when the soil moisture tension reached 300 cm. water at a 6-inch depth (short interval) and another practice wherein plots were irrigated when the soil moisture tension at the 6-inch depth reached approximately 5 atmospheres. There have been no significant differences in yields of hay between the two practices. Intermittent irrigation at the short interval required six irrigations per year and application of 8.2 acre-inches of water per ton of hay produced. Irrigating at a soil moisture tension of 5 atmospheres resulted in four irrigations per year and 5.1 acre-inches of water per ton of hay produced were required.

Effect of Irrigation Practices on Vegetative Composition

At the beginning of the experiment in 1950 all irrigation plots had substantially the same vegetative composition. The vegetative composition in 1951 is shown in figure 1. This comparison shows that continuous irrigation favored grasses and grass-like plants (sedges and rushes) and discouraged clovers. Differences in vegetative composition among plots receiving the several intermittent irrigation practices were small.

Interaction of Irrigation Practices and Fertility Treatments

In 1951, the year in which the effect of continuous irrigation was observed, a significant interaction between irrigation practices and fertility treatments occurred in all harvests in percent and yield of crude protein.

Under intermittent irrigation, the application of nitrogen fertilizer resulted in a lower protein percentage than was obtained where no nitrogen had been applied. This effect was not generally observed under continuous irrigation. Crude protein yields per acre were somewhat increased over no treatment by all rates of nitrogen fertilization under continuous irrigation in all but the aftermath harvest. Crude protein yields were not increased by nitrogen fertilization under intermittent irrigation except in the early harvest and then only where 160 pounds of nitrogen per acre had been applied. Nitrogen fertilization significantly decreased crude protein yields, compared to no fertilization, in the late and aftermath harvests where intermittent irrigation had been employed. These relations are shown in tables 2 and 3 for continuous and sprinkler irrigation.

This interaction may be partially explained by the changes in species composition that occurred (see figure 1). Under intermittent irrigation, clovers were an important part of the forage where no nitrogen had been applied. The addition of nitrogen apparently stimulated the grasses to such an extent that the clovers were suppressed and the protein percentages were decreased. Approximately 160 pounds of nitrogen per acre were required to increase the protein in the grasses sufficiently to offset the loss of the clovers. With continuous irrigation, the clovers constituted a lesser portion of the forage (see figure 1) and their suppression under nitrogen fertilization was compensated by the effect of the lower rates of nitrogen fertilizer.

The interactions between intermittent irrigations and fertilizer treatments were not significant.

Interaction of Irrigation and Harvest Management Practices

Under both continuous and intermittent irrigation practices there has been little difference in the yield of hay between the two-harvest system (early harvest plus aftermath) and the single-cut system (late harvest). In the quality factors, especially the production of crude protein,

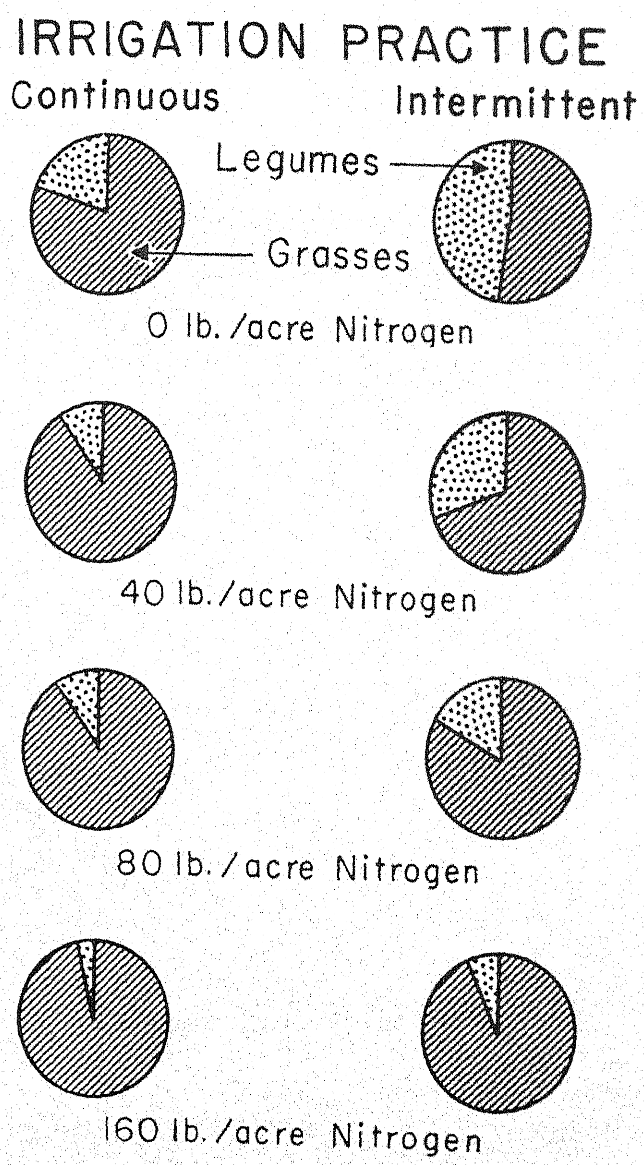

FIG. 1.—Influence of irrigation and nitrogen fertilization practices on vegetative composition, 1951.

Table 2.—Effect of irrigation practices and nitrogen fertilization on crude protein percentages* in hay, 1951, (means of native sod and native sod seeded to legumes).

Nitrogen Applied Lb./acre	Early harvest		Aftermath		Late harvest	
	Irrigation Practice					
	Continuous	Intermittent†	Continuous	Intermittent	Continuous	Intermittent
	Crude protein percentages					
0	9.5	13.8	13.9	18.5	7.6	11.3
40	9.4	12.6	12.9	17.5	7.0	8.6
80	9.5	12.4	13.4	16.4	8.0	8.2
160	10.6	13.1	11.9	14.5	7.5	9.1
L.S.D. (0.05) between nitrogen rates	0.7	1.0	N.S.	1.3	N.S.	1.0

* Data are based on hay oven-dried at 70° C.
† Intermittent irrigation here refers to the sprinkler method.

Table 3.—Effect of irrigation practices and nitrogen fertilization on pounds of crude protein per acre, 1951, (means of native sod and native sod seeded to legumes).

Nitrogen Fertilizer Applied Lb./acre	Early harvest		Aftermath		Early and aftermath		Late harvest	
	Irrigation Practice							
	Continuous	Intermittent*	Continuous	Intermittent	Continuous	Intermittent	Continuous	Intermittent
	Pounds crude protein per acre							
0	330	597	122	436	453	1032	360	639
40	380	584	122	374	501	957	396	506
80	443	595	119	338	562	932	450	547
160	528	718	118	320	646	1038	496	692
L.S.D. (0.05) between nitrogen rates	57	67	N.S.	58	84	107	66	87

* Intermittent irrigation here refers to the sprinkler method.

the two-harvest method has resulted in large improvements compared to the late harvest (see table 1).

By comparing the data in table 4, it is shown that the increases in yield of crude protein and removal of phosphorus from intermittent irrigation over continuous irrigation are two to three times as great from the two-harvest method as from the single late harvest. The same trend is indicated for hay yield although the difference between continuous and intermittent irrigation was not significant in either harvest method.

The effect becomes particularly evident when the combination of continuous irrigation and late harvest is compared with intermittent (sprinkler) irrigation and early harvest plus aftermath (table 1). Considering all seeding and fertility treatments, the former practice produced 451 pounds of crude protein and 9.62 pounds of phosphorus in 1951 compared with 1036 and 19.20 pounds for the latter practice. Under the common ranch-employed practices of continuous irrigation with a single-cutting, late harvest and no seeding or fertility treatments, a production of 349 pounds of crude protein per acre was attained. By the change in the irrigation practice to an intermittent method, crude protein production was almost doubled—to 621 pounds per acre. By the further change to the two-cutting, early harvest method, production was tripled—to 1,024 pounds of crude protein.

Table 4.—Improvement in yield and quality of hay as influenced by continuous and intermittent† irrigation, and early and late harvests, 1951.

	Early harvest plus aftermath	Late harvest
Hay yield—tons/acre	0.85‡	0.37
Crude protein yield—lbs./acre	449*	178*
Phosphorus removal—lbs./acre	6.67*	1.83*

† Intermittent irrigation here refers to the sprinkler method.
‡ Values shown were computed by subtracting the mean values for all sod management and fertility treatments under continuous irrigation from corresponding values for intermittent irrigation (table 1).
* Indicates difference is significant at 5% level.

SUMMARY

Four irrigation practices, two sod management methods, eight fertilizer treatments and two harvest management systems were investigated on an area fairly representative of the better drained high altitude meadows in Colorado. Results of the irrigation investigations are reported. The practices were evaluated in terms of hay yield, percentage and yield of crude protein, percentage and removal of phosphorus,

change in species composition, and quantity of water applied per ton of hay produced.

Intermittent irrigation practices were found to produce hay of better quality with much less irrigation water than the continuous irrigation. However, the intermittent irrigation practice did not result in significant increases in yield over the continuous irrigation except in the aftermath cutting.

There were no significant differences in yield or quality of hay among the various intermittent irrigation practices, namely, sprinkler irrigation at the short interval, and flood irrigation at short and long intervals of time. Flood irrigation at the short interval required application of more than three times as much water per ton of hay than did sprinkler irrigation at short interval. Flood irrigation at the short interval required that more water be applied per ton of hay produced and a greater number of irrigations than did flood irrigation at the long interval where water was applied when the soil moisture tension reached 5 atmospheres.

Under intermittent irrigation, the application of nitrogen fertilizers at rates up to 160 pounds of nitrogen per acre resulted in lower percentages of crude protein than where no nitrogen had been applied. Under continuous irrigation, the protein percentages were not greatly influenced by these rates of application of nitrogen. Under intermittent irrigation, yields of crude protein per acre were increased only when rates of application of nitrogen fertilizers of 160 pounds of nitrogen were applied. Under continuous irrigation, yields of crude protein per acre were somewhat increased over no treatment by all rates of nitrogen fertilization.

Under a two-harvest system (early harvest plus aftermath) the yield of crude protein and the removal of phosphorus have been significantly greater than under the single-cut system (late harvest.) However, when the two-harvest system is practiced in connection with intermittent irrigation, these increases are two to three times as great as when practiced in connection with continuous irrigation.

Continuous irrigation favored grasses and grass-like plants (sedges and rushes) and discouraged clovers. Intermittent irrigation encouraged the growth of clovers.

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Leaf Number in Mature Embryos of Inbred Lines of Dent Maize[1]

J. E. Hubbard and Earl R. Leng[2]

ATTEMPTS to analyze complex characters of the maize plant have led in recent years to increased emphasis on investigations of its morphology and development. Such investigations are especially necessary in the analysis of developmental patterns or rates. However, studies of vegetative parts, such as leaves, by conventional methods are subject to the limitation that a significant portion of the differentiation of these parts occurs during the development of the embryo, and has already been completed by the time the embryo is fully developed.

Foliage leaf number in maize is a particularly interesting character in this respect, since several leaves become definitely differentiated during the development of the embryo. Therefore, studies of leaf number, particularly if they concern rates or patterns of leaf initiation, would be incomplete without a knowledge of the "initial capital" involved, that is, the number of differentiated leaves in mature embryos of types being studied. Only a limited amount of published information bearing on this question is available. Fairchild (2) and Sass (4) have reported that mature maize embryos generally have five, but in some cases four, differentiated leaves. The bulk of the material studied by Abbe and Stein (1) also showed five differentiated leaves in the embryo. However, little information has been published on embryo leaf number in a range of maize types varying widely in maturity or total foliage leaf number, or on the possible relation of embryo leaf number to characteristics of the kernel or the mature plant.

It is the purpose of this paper to present data on the number of leaves differentiated in the mature embryos of a group of maize inbreds differing widely in total leaf number, maturity, and kernel size, and to discuss relationships observed between embryo leaf numbers and certain characteristics of the mature plants.

MATERIAL AND METHODS

Kernels used in the study of embryo leaf number were selected from selfed seed lots of 14 standard inbred lines grown at Urbana, Ill., in 1946 and 1948. Only sound, whole kernels were selected for dissection and sectioning.

[1] Contribution from the Department of Agronomy, Illinois Agr. Exp. Sta., Urbana, Ill. Based in part on a thesis submitted by the senior author to the Graduate College, University of Illinois, in partial fulfillment of the requirements for the degree of Master of Science. Published with the approval of the Director of the Illinois Agr. Exp. Sta. Received for publication Aug. 26, 1954.

[2] Formerly graduate student, now Agricultural Technologist, Northern Utilization Research Branch, U.S.D.A., Peoria, Ill., and Assistant Professor of Plant Genetics. The authors are grateful to H. N. Mehrotra for making certain of the mature-plant leaf counts reported in this paper.

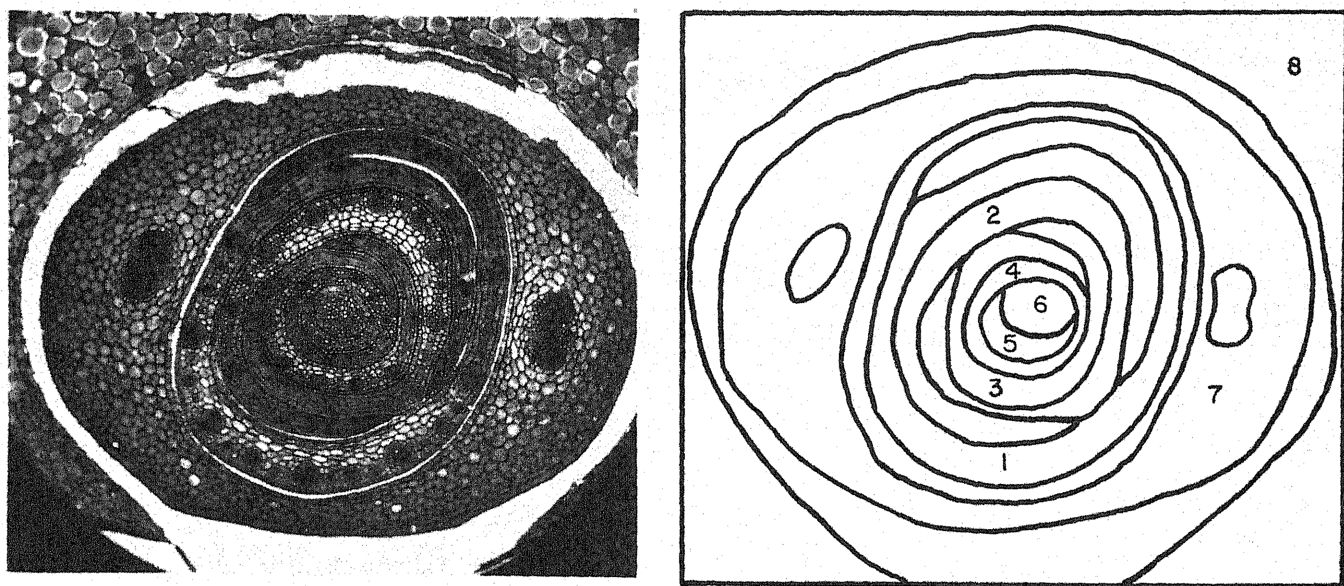

FIG. 1.—*Left:* cross-section through the shoot apex of a mature embryo of inbred line R53. *Right:* diagram of the same section, illustrating method of numbering differentiated leaves; 1–5, embryo leaves; 6, shoot apex; 7, coleoptile with its two vascular bundles; 8, scutellum.

The kernels were softened by soaking in distilled water; then the germs were carefully removed with a scalpel, fixed and embedded in paraffin. Serial cross-sections, each approximately 15 μ thick, were cut from top to base of the shoot, mounted and strained with safranin, Orange G, tannic acid and iron-alum, according to the schedule of Sharman (5).

The leaf count on each embryo was made from the single section showing the greatest degree of development of the last-differentiated leaf, nearest the shoot apex. The appearance of a typical section from an embryo of inbred R53, together with the method of numbering the embryo leaves, is shown in figure 1. A leaf was regarded as differentiated, and counted, only if the line of demarcation between the shoot apex and the leaf was distinct.

Data on total number of foliage leaves of mature plants of the inbred lines were taken in 1948, 1950 and 1953, during the course of studies which have been reported elsewhere[3] (3). Accuracy of these determinations was insured in all cases by marking the fifth and tenth leaves during the earlier part of the growing season, tagging the internode above the tenth leaf, and making final counts after tasseling.

RESULTS AND DISCUSSION

The inbred lines used in this study varied in total mature-plant foliage leaf number from less than 16 to more than 25, in maturity from very early to very late, and in kernel size from very small to exceptionally large (see table 1). Despite the wide range of variability in these characters, leaf number in the mature embryos of the lines studied was found to be remarkably uniform. No embryo of any line was found to have less than four or more than five differentiated leaves. The mean embryo leaf number of the 14 lines studied was 4.86, and only two inbreds, K4 and W23, had means of less than 4.7 embryo leaves. Of all embryos examined, approximately 86% were found to have five differentiated leaves.

[3] Mehrotra, H. N. Inheritance of foliage leaf number in maize. Unpub. Ph.D. thesis. University of Illinois Library, Urbana, Ill. 1954.

Table 1.—Leaf number in mature embryos of 14 inbred lines of corn, and its association with total foliage leaf number, maturity, and kernel weight.

Inbred line	Total no. foliage leaves produced	Mean no. days to half-silk	Kernel weight, grams per 100 kernels	Leaf number in mature embryos
R53	15.7	64	28.1	5.0
W26	16.1‡	68	21.1	5.0
W23	18.1	70	15.2	4.2
L317	19.0	77	24.1	4.9
38–11	20.3	75	26.3	5.0
K201-C	20.4‡	81	38.9	5.0
K155	20.8‡	78	25.8	4.9
C.I. 7	21.3‡	77	27.5	4.7
K4	21.4	83	21.1	4.5
T8	21.6‡	77	30.0	4.9
WF9	21.8	69	28.3	5.0
C.I.21E	22.1‡	81	31.0	5.0
C.I.3A	22.1‡	77	27.5	4.7
Kys	25.4	83	21.2	5.0
Means	20.4	75.7	26.2	4.86

Coefficients of correlation between:

Embryo leaf number and mature-plant leaf number:	+0.118†
Embryo leaf number and days to half-silk:	+0.004†
Embryo leaf number and kernel weight:	+0.610*

* Significant (5% level).
† Not significant.
‡ Determination made and furnished by H. N. Mehrotra.

Correlation coefficients calculated between embryo leaf number and total foliage leaf number, days to half-silk, and kernel weight indicated a significant positive association between embryo leaf number and kernel weight, but not between embryo leaf number and the other characters (see table 1). The lack of association between embryo leaf number and total foliage leaf number is illustrated by the fact that the inbreds R53 and Kys, which had the lowest and highest total foliage leaf numbers, respectively, in this study, both were found to have five differentiated leaves in all

embryos examined. These same inbred lines also represented the greatest extremes in maturity of the inbreds studied, differing 19 days in the number of days to half-silk, yet had identical embryo leaf numbers.

The observed lack of association between embryo leaf number and mature-plant leaf number indicates that the latter character is essentially independent of developmental conditions which may influence the number of leaves differentiated during embryogeny. In other words, total foliage leaf number in maize apparently is not controlled or affected significantly by the "initial capital" of differentiated leaves in the fully-developed embryo. Studies involving only the total *number* of foliage leaves produced can therefore be conducted without reference to variations in the number of leaves differentiated in the embryo. However, sufficient variability apparently exists in embryo leaf number to warrant its consideration in studies which are concerned with the *rate* of leaf initiation or development.

SUMMARY

The number of leaves differentiated in mature embryos was studied in 14 inbred lines of maize, and was found to be five in most cases. No embryo was found with less than four or more than five differentiated leaves. Only two of the lines studied were found to have mean embryo leaf numbers less than 4.7.

Although the inbred lines studied represented a wide range of variation in total foliage leaf number and maturity, no association was found between these characters and embryo leaf number. A statistically significant positive correlation ($r = +0.610$) was found between embryo leaf number and kernel weight.

It was concluded that total production of foliage leaves in maize is not controlled or affected significantly by the "initial capital" of differentiated leaves in the fully-developed embryo.

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Air Temperatures in the Microclimate at Four Latitudes in the Northeastern United States[1]

V. G. Sprague, A. V. Havens, A. M. Decker, and K. E. Varney[2]

IT IS recognized that atmospheric conditions close to a surface (bare ground or a vegetative cover) differ markedly from those recorded by sheltered instruments usually placed at a height of 5 feet or more above the ground level. Where data are collected for weather forecasting, the instruments are purposely placed to avoid the microclimate. The weather forecaster must have a representative large scale picture of the atmosphere on a continental (or even hemispherical) basis. Strictly localized weather conditions must be excluded.

In recent years, the importance of microclimate in agriculture has become increasingly evident. Measurements of the components of the microclimate have been made at several widely separated locations. The usefulness of such investigations could be substantially extended by organizing a network of microclimate stations. These could provide information indicating the regional variation of the vertical gradient of climate between the microlayer (lowest few inches of the atmosphere), and the macro or standard layer (about 5 feet above ground).

Such a network was established on a limited scale in connection with a cooperative 3-year strain test of forage varieties conducted cooperatively by seven state Agricultural Experiment Stations and the U. S. Pasture Laboratory. At four locations, Maryland, New Jersey, Pennsylvania, and Vermont, air temperatures were measured at two specified heights above a uniform ground cover for 3 successive years, 1951–1953.[3]

OBSERVATIONS AND METHODS

The air temperatures reported were measured at heights of 3 inches and 5 feet above a well fertilized Kentucky bluegrass sod that was clipped to maintain the grass at a height of 1½ to 2½ inches. At each location, (see table 1), the sensing elements were located on relatively level land free from the influence of cold air drainage.

Temperature recording potentiometers were connected to No. 30 B&S gage copper-constantan thermocouples that were shielded from solar and sky radiation. In Maryland, Pennsylvania and Vermont, air temperatures were obtained at

[1] An investigation carried on in connection with Regional Forage Crop Project NE-10. Contribution No. 135 of the U. S. Regional Pasture Research Laboratory, Field Crops Research Branch, A.R.S., U.S.D.A., State College, Pa., in cooperation with the Maryland, New Jersey, and Vermont Agr. Exp. Stations. Received for publication Aug. 26, 1954.

[2] Agronomist, U. S. Pasture Research Laboratory; Assistant Professor of Meteorology, Rutgers University; Assistant Professor of Agronomy, University of Maryland; and Assistant Professor of Agronomy, University of Vermont, respectively.

[3] Limited data reported by New York and West Virginia indicate similar general relationships of temperature in the microclimate.

2-hour intervals during the day (6 a.m. to 6 p.m.) and at 3-hour intervals during the night. In New Jersey, similar data were obtained with shielded maximum and minimum thermometers read daily. Daily maximum and minimum temperatures at all stations were summarized by calendar months.

During the winter, temperatures at the 3-inch level were occasionally influenced by a snow cover. At the Maryland and New Jersey station this occurred too infrequently to be of significance, but at Vermont it doubtless did influence the results, and also to some extent at Pennsylvania.

RESULTS AND DISCUSSION

As indicated earlier[4,5] the daily range of temperature at the 3-inch level is considerably greater than at the standard 5-foot height. This is also shown in table 2 for the present study and may be seen graphically in figures 1 and 2. A rather pronounced trend of differences in the daily temperature ranges between the two heights is evident at all four locations, (see figure 2). From April through October the greater daily ranges at the 3-inch level are marked while during the winter season, the differences between the two levels are less. The smaller winter ranges result from more cloudiness and stronger winds which decrease the differences between the microclimate and macroclimate. During the winter the greater differences in daily temperature ranges (figure 2) occurred at Maryland and New Jersey, to a lesser extent at Pennsylvania, and to a much less extent in Vermont. The fact that the thermocouple at the 3-inch height in Vermont was more frequently insulated by a snow cover, than at the other stations, is a partial explanation for the results. In addition, winters are normally more cloudy and windy at Vermont than at the other locations.

Monthly averages of the mean daily maximum and mean daily minimum temperatures at the 3-inch height are compared with those at the 5-foot height at the same stations (see figure 3). The greater daily ranges at the 3-inch level in summer are generally the result of higher maxima rather than of lower minima. This explains the tendency toward somewhat higher mean temperatures at the 3-inch level during the summer (figure 1).

At Burlington, Vt., during the months of November, January, February, and March, the mean daily temperature range at the 3-inch level under the snow is actually smaller than at the 5-foot level in the air. The microclimate under a persistent snow cover may be considerably less severe even in a cold climate than in a warm climate where a snow cover

[4] Geiger, R. The climate near the ground. Harvard University Press, Cambridge, Mass. 1950.

[5] Sprague, V. G., Neuberger, Hans, Orgell, W. H., and Dodd, A. V. Air temperature distribution in the microclimatic layer. Agron. Jour. 46:105–108. 1954.

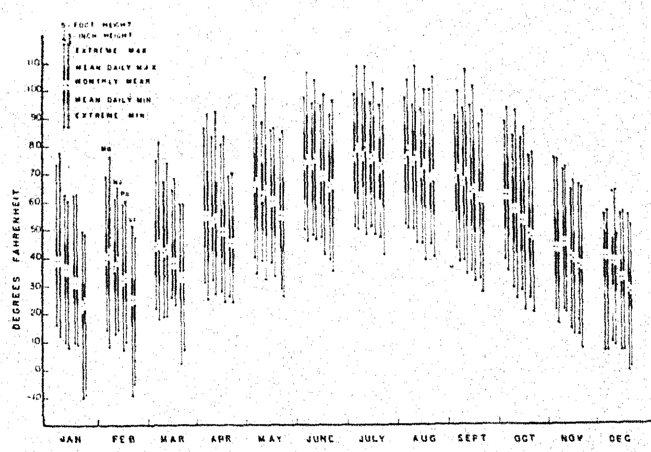

FIG. 1.—Air temperature characteristics 3 inches and 5 feet above clipped Kentucky bluegrass sods in Maryland, New Jersey, Pennsylvania, and Vermont. Average records obtained during 1951 to 1953, inclusive, except for August through November in Maryland where data for 1951 only are available.

Table 1.—Latitude and elevation above (mean) sea level of cooperating stations.

Station	Latitude	Elevation	Miles from coast*
College Park, Md.	38° 59′	95 ft.	75
New Brunswick, N. J.	40° 38′	100 ft.	25
State College, Pa.	40° 48′	1195 ft.	200
Burlington, Vt.	44° 48′	330 ft.	150

* Approximate distance from the Atlantic Ocean coastline.

Table 2.—Mean daily temperature range* (degrees F.) at 3 inches and 5 feet above ground level, 1951 to 1953, inclusive, at four experiment stations.

Month	Maryland		New Jersey		Pennsylvania		Vermont	
	Ranges degrees F., at indicated heights							
	5 ft.	3 in.	5 ft.	3 in.	5 ft.	3 in.	5 ft.	3 in.
January	16	23	17	20	14	14	16	14
February	20	27	17	23	14	16	17	14
March	19	27	18	21	16	20	16	15
April	21	32	20	25	17	22	16	20
May	24	33	23	32	19	24	21	26
June	23	33	26	35	19	27	22	29
July	25	36	22	33	22	29	21	29
August	24†	33†	21	32	22	29	21	28
September	26†	34†	24	37	24	30	20	25
October	25†	31†	23	31	21	29	18	22
November	20†	27†	21	25	14	18	13	14
December	17	23	17	21	14	13	14	13

* Mean daily maximum minus mean daily minimum temperatures.
† These data are for the year 1951; data for 1952 and 1953 at the 3-inch height are not available.

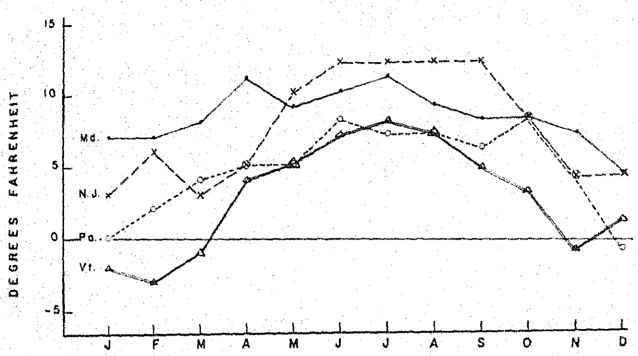

FIG. 2.—Difference between the mean daily range of air temperature at 3 inches and at 5 feet above clipped Kentucky bluegrass sods in Maryland, New Jersey, Pennsylvania and Vermont (The 5-foot height is taken at the zero line). The differences are consistently greater at the southern stations, and are greatest during midsummer.

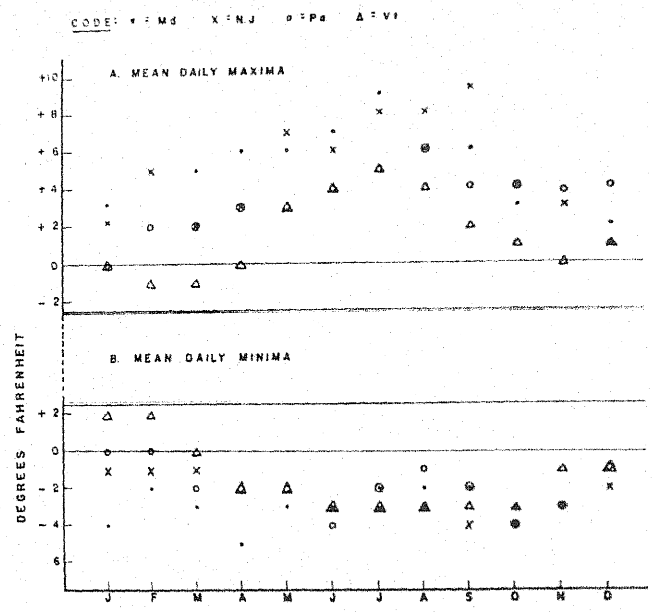

FIG. 3.—Difference in the average monthly maximum and minimum temperature of air at heights of 3 inches and 5 feet above Kentucky bluegrass sods in Maryland, New Jersey, Pennsylvania, and Vermont. The 5-foot height is taken as the zero line.

is present only intermittently if at all. Under these latter conditions low growing crops are exposed to much greater extremes in temperature and much more rapid and frequent temperature changes.

SUMMARY

Daily maximum and minimum air temperatures were measured at 3 inches and 5 feet above clipped grass sods in Maryland, New Jersey, Pennsylvania and Vermont during 1951 to 1953, inclusive.

Greatest daily ranges in maximum air temperatures were observed during the summer 3 inches above ground level and particularly at the more southern locations. In these same locations during the winter, greatest extremes in minimum temperatures occurred near ground level. At the northern stations snow cover during the winter insulated the thermocouples near ground level and reduced their diurnal change in temperatures.

Book Reviews

THE PLANT QUARANTINE PROBLEM

Vol. XI Annales Cryptogamici et Phytopathologici, by W. A. McCubbin. Copenhagen, Denmark, Ejnar Munksgaard. 1954. 255 pages. $4.80.

"A General Review of the Biological, Legal, Administrative and Public Relations of Plant Quarantines with Special Reference to the United States Situation," is the descriptive subtitle of this extremely interesting and exceptionally literate work. The author of this review retired from the U.S.D.A. Bureau of Entomology and Plant Quarantine in 1950 after more than 20 years of service. He had previously served in the state of Pennsylvania and in the Canadian federal service. This rich experience well qualified him for the task of bringing together under one cover the several aspects of plant quarantine. This summary is written not for plant quarantine officials, but for workers in related fields of research and teaching, for writers, editors, farm organization leaders, business people, and—one would hope—politicians. Writing thus for such a broad, yet specialized and responsible audience, the author has given his subject a deserved universal appeal, and has accomplished the task with singular skill.

Separate chapters deal with the problem in the following aspects: The Biological Background, Social and Economic Features, Legal Features, Administrative Aspects. Other chapters cover Appraisal and Outlook and the World Situation.

To illustrate the practical problems arising in the above aspects of quarantine, another chapter considers the potato root parasite, the golden nematode, which has been limited to the Long Island area since it was introduced some 24 years ago. An appendix lists the quarantines issued by USDA on plant disease subjects from the inception of the Plant Quarantine Act in 1912.

Mr. McCubbin is confident that an effective quarantine system in the U. S. is both possible and attainable. The high cost of such a system could be justly weighed against the crop losses resulting from a succession of introduced pests, the burdens imposed on private individuals for pest control, and the heavy public expenditures for research, extension and domestic quarantine activities. "The building up of present quarantine accomplishment into a completely adequate national protective system," says Mr. McCubbin, "would appear to require only the exercise of those capabilities so characteristic of American genius—patient research, sound, practical organization, and the intelligent support of an understanding public."

While the international aspects of quarantine present each individual nation with added problems, there is ample groundwork already laid in the various agreements between nations, the author points out, proving that nations recognize that so far as pests are concerned, "this is truly 'one world.' "

ELEMENTS OF ECOLOGY

By George L. Clarke. New York, John Wiley and Sons. 1954. 534 pages. $7.50.

What the physiologist and psychologist are to the study of the human organism, the ecologist is to the entire world of living things. The former interest themselves in the dynamics of human adjustment—in the integrated forces that determine the course of human life; and the general ecologist directs his attention to the

dynamic interplay of the forces relate *all* forms of life in one way or another and ultimately to each other.

Dr. Clarke has made the significance of his subject extremely clear from the first page of the preface on through the entire book. He presents a complete ecological picture of plant and animal life and the interrelationship of both and the physical forces in their environment.

Main chapter headings include The Viewpoint of Modern Ecology, the Medium, the Substratum, Water, Temperature, Light, Oxygen and Carbon Dioxide, Nutrients, Relations within the Species, Relations between Species, The Community, Success and Fluctuation, and Dynamics of the Ecosystem.

As an introduction to the fundamental relationships of ecology, the book is not only significant for students of ecology for whom it is primarily intended, but should be of great value to general biology students. And certainly through a book of this scope, all crop and soil scientists will be enriched by a more than nodding acquaintance with the field of study which relates their own immediate work to the vast environment of other living things. The presentation is clear enough to benefit a general reader.

Dr. Clarke is zoologist at Harvard University and marine biologist at Woods Hole Oceanographic Institution.

THE CARE AND FEEDING OF GARDEN PLANTS

Published by the American Society for Horticultural Science and the National Fertilizer Association, Washington, D. C. 1954. 184 pages. $3.00.

Home gardening and landscaping is undoubtedly the proto-type of all "do-it-yourself" projects. Here is a unique handbook for those householders who indulge in the pastime for whatever the reason, economic, psychological or sentimental. The helpful information is so varied, reliable and understandable that this volume should earn a wide readership; and perhaps as a medium for disseminating scientifically founded agronomic principles on a popular level, it will turn increasing numbers of city dwellers and farmers as well to the profits and pleasures of gardening.

Chapter headings indicate the broad coverage: How Plants Grow, If You Want a Good Lawn, Shrubs for the Home Grounds, Trees for the Home Grounds, House Plants Bring Nature's Beauty Indoors, Fertilizers for Garden Flowers, How About a Vegetable Garden? and Small Fruits for the Home Garden.

Sixty-five color plates help the reader diagnose nutrient deficiencies and insect damage in various plants and fruits.

The book offers a welcome answer to much misleading and unfounded information on "organic" gardening. The need for organic matter is not challenged; but the reader is advised of its practical cost in sufficient quantity alone to be beneficial. Authors point out that organic matter and commercial fertilizer complement each other, and are both needed in the average garden.

Contributors are Daniel G. Aldrich, Jr., California Agr. Exp. Sta.; H. G. Gauch, Univ. of Maryland; Fred V. Grau, West Point Products Corp.; Glenn W. Burton, U.S.D.A., Tifton, Ga.; N. W. Stuart, U.S.D.A.; E. P. Christopher, University of Rhode Island; Norman F. Childers, New Jersey Agr. Exp. Sta.; James M. Beattie, Ohio Agr. Exp. Sta.; Conrad P. Link, Univ. of Maryland; John G. Seely, Pennsylvania State Univ.; R. Milton Carleton, Vaughan Seed Co., Chicago; Charles J. Gould, Washington State College; R. L. Carolus, Michigan Agr. Exp. Sta.; O. A. Lorenz, California Agr. Exp. Sta.

BIG DAM FOOLISHNESS

By Elmer Peterson. New York. Devin–Adair Co. 1954. 224 pages. $3.50.

It is the author's conviction, clearly presented, that in the name of flood control our natural soil resources are being mismanaged grossly according to a socialistic pattern expanding toward national dimensions under pork-barrel policies. As the figurative title implies, the author believes that the Army Engineering Methods of trying to "cure" floods in the more level, agricultural Mid-continent by putting big dams into the larger stream "stems", is bureaucratic foolishness.

This book is a clear exposition of the fallacies in believing that big dams will control floods when the infiltration, or "insoak", of rain water at the point where it falls on the land will be the only real prevention. It presents evidence from soil conservation as flood prevention on farm demonstrations which are national dividend paying investments for conserving soils while improving the farmer's earning powers. For the author, prevention of runoff water by infiltration into the soil—not the cure of floods by big dams in the lower streams, is the proper approach to the flood problem in the Mid-continent.

Now that the fact is slowly dawning on us that a growing population calling for high food standards cannot long be maintained on shrinking numbers of arable acres of dwindling protein production each, it is high time that we become concerned about our soils and the rain water moving them and itself off to the sea in what is appropriately christened with the new name of "land-soup". It is high time also that not only rural folks, but the urban population as well, become alert to the political developments formulating the policies associated with "flood control". The author convinces us that there is a far-flung call for a righteous indignation against the so-called flood control that fails to rise above all that he found in it.—W. A. ALBRECHT.

ASIA, EAST BY SOUTH

By Joseph E. Spencer. New York. John Wiley and Sons. 1954. 453 pages. $8.50.

Whether friend, foe or neutral, the southeast Asian will continue to have considerable influence on the life of the North American for some time to come. Joseph E. Spencer here offers the latter a detailed description of that important corner of the world, and an urgently needed explanation of how and why the varied peoples and nations of southeast Asia have developed the stamp and character by which they are known to the rest of the world.

In this timely volume, Joseph Spencer, speaking primarily to the western reader, explains the environmental bases for the particular cultures which have developed in southeast Asia. The soil scientist and agronomist will appreciate the chapters on soils, plants, geomorphology and mineral geography. Other major topics include the geography of animal distribution, the role of fish and fishing in regional economy, the geography of health and disease. Of particular interest to the American reader is the breakdown into separate discussions of each country: India, Burma, Thailand, Indonesia, Malaya, the Indies, the Philippines, China, Manchuria, Tibet, Korea and Japan.

To understand the complexities of political, economic, or military action with or against any one or any combination of these nations, one must be familiar with the unique local and regional conditions which helped create individual political entities. Dr. Spencer points these out clearly and reliably. During the 1930's he became intimately acquainted with his subject when he was with the Ministry of Finance of the Chinese Nationalist government. Wartime service took him further in India, Ceylon, Burma and western China. He is now chairman of the geography department at the University of California, Los Angeles.

Science Reports of the Research Institutes, Tohoku University, Series D (Agriculture) Vol. 5. Tohoku University, Sendai, Japan. Research papers in English of which the following are representative: "Response of rice plant varieties to amounts of ammonium sulphate," "Physiological behavior of hydrogen sulfide in the rice plant," "Observations on the behavior of soft-rot bacteria in the rhizophere of Chinese cabbage."

Soil Science Annual, 1954. Polish Soil Science Society, Warsaw, Poland. Technical papers on recent research in Poland. Some titles are: "Classification of Polish soils by the Polish Soil Science Society," "Polish soils," "The problem of natural classification of soils," "A system of soil classification recently adopted in the USSR," "A new method for determining porosity, specific gravity and air capacity of soils."

Bylaws—Crop Science Divisions, American Society of Agronomy

A. Name

The name of the Divisions shall be The Crop Science Divisions, American Society of Agronomy.

B. Objectives

The general objectives of The Crop Science Divisions shall be to advance research, extension and teaching of all basic and applied phases of The Crop Sciences and to cooperate with all other organizations and societies similarly interested in the improvement, production, management and utilization of field crops.

C. Membership

The membership of The Crop Science Divisions shall be those members of The American Society of Agronomy who indicate to the Society their interest in the general objectives of the Divisions.

D. Officers

Section 1.—The officers of The Crop Science Divisions shall be a President, a Vice President, who is the president-elect, and an Executive Secretary. The Executive Secretary shall be the Executive Secretary of The American Society of Agronomy.

Section 2.—The Vice President shall be elected by mail ballot sent to all members by the Executive Secretary at least 60 days in advance of the annual meeting. A Nominating Committee appointed by the President shall propose the names of at least 2 but not more than 4 nominees for the position. During their terms of office, chairmen-elect of the Divisions are not eligible to be nominees for the Vice Presidency.

Section 3.—The Vice President shall serve as Program Chairman of the Crop Science Divisions.

Section 4.—The President and Vice President shall serve from the close of the annual business meeting of The Crop Science Divisions to the close of the next business meeting. The Vice President shall succeed to the presidency at the close of the annual business meeting or earlier if for any reason the President cannot officiate during his term of office.

Section 5.—The duties of the President, Vice President and Executive Secretary shall be those which usually pertain to the respective offices held or as prescribed by the by-laws.

E. Executive Committee

The Executive Committee of The Crop Science Divisions shall consist of the President, the Vice President, the immediate Past President, the Chairmen and Vice Chairmen of the respective Divisions and the Executive Secretary. The Executive Committee shall act as the governing body of The Crop Science Divisions and shall prepare all program regulations.

F. Divisions

Section 1.—The professional groups constituting the Crop Science Divisions shall be designated as Divisions in the following fields:

Division 7—Breeding, Genetics and Cytology
Division 8—Physiology and Ecology
Division 9—Crop Production and Management
Division 10—Weeds and Weed Control
Division 11—Turf Management
Division 12—Seed Production and Technology

Section 2.—New Divisions may be organized by members with a common interest in a particular field upon approval of the Executive Committee of The Crop Science Divisions and in accordance with the by-laws of The American Society of Agronomy. Divisions may be terminated (1) by a vote of 2/3rds of the membership following 60 days notice to the membership by the Executive Committee, or (2) by a 2/3rds vote of the Executive Committee if a Division fails for 2 years to conduct a 1/2 day session of presented papers at the annual meetings.

Section 3.—The Divisions may provide in their organization for sub-divisions dealing with applied phases.

Section 4.—The officers of each Division shall be a Chairman, a Vice Chairman, who is a chairman-elect, and the immediate Past Chairman.

Section 5.—The Chairman shall preside at the annual business meeting of the Division. The Chairman and Vice Chairman in cooperation can designate themselves or another member to preside at other sessions of the Division.

Section 6.—The Vice Chairman shall be elected by ballot at the scheduled business meeting of the Division from a slate prepared by a Nominating Committee consisting of the 3 Past Chairmen.

Section 7.—The Vice Chairman shall succeed automatically to the Chairmanship at the close of the annual meeting or earlier if the Chairman for any reason cannot officiate during his term of office.

Section 8.—The Vice Chairman shall act as the program chairman for the Division.

Section 9.—The officers of the Divisions shall be responsible for the policies of the Divisions, subject to the approval of the Executive Committee.

G. Meetings

Section 1.—There shall be held annually a meeting of The Crop Science Divisions for presentation of papers and the transaction of business. Divisional and general sessions shall be held, at least one of which shall be a business session.

Section 2.—The time and place of the meetings shall be those determined by The American Society of Agronomy.

Section 3.—Five percent of the paid-up membership of The Crop Science Divisions shall be considered a quorum. Prior to or at the time of each meeting the Treasurer of The American Society of Agronomy shall certify to the President the number of paid-up members.

Section 4.—At least one of the authors of papers must be a member in good standing in The American Society of Agronomy except in the case of papers presented by invitation.

H. Committees

Section 1.—The standing committees of The Crop Science Divisions shall be appointed by the President. They shall be those as authorized by the Crop Science Divisions or the Executive Committee.

Section 2.—The program committee for the annual meeting shall consist of the President and the Vice President. The President shall be responsible for the general sessions of The Crop Science Divisions. The Vice President, with the advice and cooperation of the President, shall be responsible for final assembly of the Divisional programs and coordination of the overall program of the meetings.

I. Amendments

Section 1.—Any 20 or more members of The Crop Science Divisions may initiate a proposed amendment to these by-laws. The amendment shall be submitted to the membership with recommendations of the Executive Committee either at the next annual meeting or by mail ballot.

Section 2.—The Executive Committee may propose amendments to these by-laws at anytime either by mail ballot or at the annual meeting.

Section 3.—The Executive Committee shall submit the proposed amendments to the membership at least 60 days before they are voted on. Adoption of a proposed amendment shall require a majority vote of those present at an annual meeting or, if by mail ballot, a majority of all ballots returned within 60 days after the date of the original mailing.

Agronomic Affairs

MEETINGS

Feb. 7–9, Southern Branch, American Society of Agronomy, Brown Hotel, Louisville, Ky.

Mar. 6–12, consecutive meetings, American Society of Photogrammetry, March 6–9; American Congress of Surveying and Mapping, March 9–12, Shoreham Hotel, Washington, D. C.

Aug. 1–6, 3rd International Congress of Biochemistry, Brussells, Belgium.

Aug. 15–19, American Society of Agronomy and Soil Science Society of America, University of California College of Agriculture, Davis.

April 27–29, Arid Lands Symposium (AAAS) Albuquerque, N. Mex.

OFFICERS AND DIRECTORS, 1955, AMERICAN SOCIETY OF AGRONOMY

OFFICERS

PRESIDENT

G. G. POHLMAN, Univ. of West Virginia, Morgantown, W. Va.

VICE-PRESIDENT

I. J. JOHNSON, Iowa State College, Ames, Iowa

PAST-PRESIDENT

C. J. WILLARD, Ohio State University, Columbus, Ohio

EXECUTIVE SECRETARY

L. G. MONTHEY, American Society of Agronomy, Madison, Wis.

BOARD OF DIRECTORS

G. G. POHLMAN, I. J. JOHNSON, C. J. WILLARD, and L. G. MONTHEY. *(Society officers as listed above).*

M. B. RUSSELL, University of Illinois, Urbana, Ill., *President, Soil Science Society of America.*

G. H. STRINGFIELD, Ohio Agricultural Experiment Station, Wooster, Ohio, *President, Crop Science Divisions.*

J. C. LOWERY, Alabama Polytechnic Institute, Auburn, Ala., *President, Agronomic Education Division.*

DIVISION REPRESENTATIVES

(Most recent past chairmen and their alternates, the newly-elected chairmen).

Division I: Past chairman, H. R. HAISE, U.S.D.A., Fort Collins, Colo.; *chairman,* W. DERBY LAWS, Texas Research Foundation, Renner, Tex.

Division II: Past chairman, C. A. BLACK, Iowa State College, Ames, Iowa; *chairman,* G. D. SHERMAN, University of Hawaii, Honolulu, T. H.

Division III: Past chairman, J. P. MARTIN, University of California, Riverside, Calif.; *chairman,* F. E. BROADBENT, Cornell University, Ithaca, N. Y.

Division IV: Past chairman, K. C. BERGER, University of Wisconsin, Madison, Wis.; *chairman,* D. G. ALDRICH, University of California, Riverside, Calif.

Division V: Past chairman, O. C. ROGERS, U.S.D.A., Beltsville, Md.; *chairman,* C. P. WHITESIDE, Michigan State College, East Lansing, Mich.

Division V-A: Past chairman, JOHN L. RETZER, U. S. Forest Service, Fort Collins, Colo.; *chairman,* DONALD P. WHITE, New York State College of Forestry, Syracuse, N. Y.

Division VI: Past chairman, P. J. ZWERMAN, Cornell University, Ithaca, N. Y.; *chairman,* W. H. ALLAWAY, U.S.D.A., Beltsville, Md.

Division VII: Past chairman, PAUL H. HARVEY, North Carolina State College, Raleigh, N. C.; *chairman,* E. H. STANFORD, University of California, Davis, Calif.

Division VIII: Past chairman, DALE SMITH, University of Wisconsin; *chairman,* M. L. PETERSON, University of California, Davis.

Division IX: Past chairman, B. A. BROWN, University of Connecticut: Storrs, Conn.; *chairman,* R. M. LOVE, University of California, Davis. Calif.

Division X: Past chairman, HUGH INGLIS, University of Georgia, Athens, Ga.; *chairman,* C. S. GARRISON, U.S.D.A., Beltsville, Md.

Division XI: Past chairman, W. H. DANIEL, Purdue University, Lafayette, Ind.; *chairman,* J. R. WATSON, Toro Mfg. Corp., Minneapolis, Minn.

Division XII: Past chairman, R. L. TIMMONS, Utah State Agricultural College, Logan, Utah; *chairman,* F. W. SLIFE, University of Illinois, Urbana, Ill.

Division XIII: Past chairman, G. C. KLINGMAN, North Carolina State College, Raleigh, N. C.; *chairman,* J. C. LOWERY, Alabama Polytechnic Institute, Auburn, Ala.

REGIONAL REPRESENTATIVES

Western Branch: D. R. MCALLISTER, Utah State Agricultural College, Logan, Utah.

North Central Branch: E. F. FROLIK, University of Nebraska, Lincoln, Nebr.

Southern Branch: ERIC WINTERS, University of Tennessee, Knoxville, Tenn.

Northeastern Branch: R. A. STRUCHTEMEYER, University of Maine, Orono, Me.

OTHER ALTERNATES

D. W. THORNE, *vice president, Soil Science Society of America,* Utah State Agricultural College, Logan, Utah.

G. O. MOTT, *vice president, Crop Science Divisions,* Purdue University, Lafayette, Ind.

OFFICERS OF THE SOIL SCIENCE SOCIETY OF AMERICA 1955

PRESIDENT

M. B. RUSSELL, University of Illinois, Urbana, Ill.

VICE PRESIDENT

D. D. THORNE, Utah State Agricultural College, Logan, Utah.

PAST PRESIDENT

E. TRUOG, University of Wisconsin, Madison, Wis.

SECRETARY-TREASURER

L. G. MONTHEY, Soil Science Society of America, Madison, Wis.

Division I—Soil Physics

Chairman, W. DERBY LAWS, Texas Research Foundation, Renner, Tex.

Vice chairman, STERLING A. TAYLOR, Utah State Agricultural College, Logan, Utah.

Past chairman, H. R. HAISE, U.S.D.A., Fort Collins, Colo.

Division II—Soil Chemistry

Chairman, G. DONALD SHERMAN, University of Hawaii, Honolulu, T. H.

Vice chairman, R. F. REITEMEIER, Division of Soil Management, U.S.D.A., Beltsville, Md.

Past chairman, C. A. BLACK, Iowa State College, Ames, Iowa.

Division III—Soil Microbiology

Chairman, F. E. BROADBENT, Cornell University, Ithaca, N. Y.

Vice chairman, ROBERT L. STARKEY, Rutgers University, New Brunswick, N. J.

Past chairman, J. P. MARTIN, University of California, Riverside, Calif.

Division IV—Soil Fertility and Fertilizers

Chairman, W. L. NELSON, American Potash Institute, Lafayette, Ind.

Vice chairman, D. G. ALDRICH, University of California, Riverside, Calif.

Past chairman, K. C. BERGER, University of Wisconsin, Madison, Wis.

Subdivision IV-A—Organic Soils

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Vice chairman, A. E. KRETSCHMER, JR., University of Florida, Belle Glade, Fla.
Past chairman, R. E. LUCAS, Michigan State College, East Lansing, Mich.

Subdivision IV-B—Plant Nutrients

Chairman, P. W. GULL, Spencer Chemical Co., Kansas City, Mo.
Vice chairman, G. E. SMITH, University of Missouri, Columbia, Mo.

Division V—Soil Genesis, Morphology, Classification and Cartography

Chairman, E. P. WHITESIDE, Michigan State College, East Lansing, Mich.
Vice chairman, ROY SIMONSON, Soil Survey, U.S.D.A., Beltsville, Md.
Past chairman, O. C. ROGERS, U.S.D.A., Beltsville, Md.

Division V-A—Forest and Range Soils

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Vice chairman, C. T. YOUNGBERG, Oregon State College, Corvallis, Oreg.
Past chairman, JOHN C. RETZER, U. S. Forest and Range Experiment Station, Fort Collins, Colo.

Division VI—Soil Conservation, Irrigation, Drainage, and Tillage

Chairman, W. H. ALLAWAY, U.S.D.A., Beltsville, Md.
Vice chairman, R. M. HAGAN, University of California, Davis, Calif.
Past chairman, P. J. ZWERMAN, Cornell University, Ithaca, N. Y.

OFFICERS OF THE CROP SCIENCE DIVISIONS 1955

PRESIDENT

C. H. STRINGFIELD, Ohio Agricultural Experiment Station, Wooster, Ohio.

VICE PRESIDENT

G. O. MOTT, Purdue University, Lafayette, Indiana.

PAST PRESIDENT

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DIVISION VIII—PHYSIOLOGY AND ECOLOGY

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Vice chairman, W. K. KENNEDY, Cornell University, Ithaca, N. Y.
Past chairman, DALE SMITH, University of Wisconsin, Madison.

DIVISION IX—CROP PRODUCTION AND MANAGEMENT

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Vice chairman, M. A. HEIN, U.S.D.A., Beltsville, Md.
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Vice chairman, CHARLES WILSON, 815 Oeste Drive, Davis, Calif.
Past chairman, W. H. DANIEL, Purdue University, Lafayette, Ind.

DIVISION XII—WEED CONTROL

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Vice chairman, R. J. ALDRICH, U.S.D.A., Rutgers University, New Brunswick, N. J.
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Past chairman, G. C. KLINGMAN, North Carolina State College, Raleigh, N. C.

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Vice chairman, KENNETH PATTERSON, Washington State College, Pullman, Wash.
Past chairman, N. C. BRADY, Cornell University, Ithaca, N. Y.

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Chairman, R. M. SWENSON, Michigan State College, East Lansing, Mich.
Vice chairman, H. D. FOTH, Texas A and M College, College Station, Tex.
Past chairman, E. T. YORK, North Carolina State College, Raleigh, N. C.

APRIL 1 IS FIRST DEADLINE FOR 1955 ANNUAL MEETING PAPERS

April 1 is the deadline for filing titles and abstracts of papers to be given at the 1955 annual meetings of the American Society of Agronomy and Soil Science Society of America. These should be submitted to divisional program chairman on that date.

Members are asked to indicate the time required for delivering the paper. Talks longer than 15 minutes must be cleared with the division program chairman.

Program chairmen are as follows:

Iver J. Johnson, General Program Chairman

SOIL SCIENCE DIVISIONS (Soil Science Society of America), D. W. THORNE, vice-president in charge of program.

Div. I (Soil Physics): STERLING TAYLOR, Utah State Agricultural College, Logan, Utah.
Div. II (Soil Chemistry): R. F. REITEMEIER, USDA Plant Industry, Station, Beltsville, Md.
Div. III (Soil Microbiology): R. L. STARKEY, Rutgers University, New Brunswick, N. J.
Div. IV (Soil Fertility, Fertilizers and Plant Nutrition): D. G. ALDRICH, California Citrus Experiment Station, Riverside, Calif.
Subdiv. IVa (Organic Soils): A. E. KRETSCHMER, JR., Florida Everglades Experiment Station, Belle Glade, Fla.
Subdiv. IVb (Plant Nutrients): G. E. SMITH, University of Missouri, Columbia, Mo.
Div. V (Soil Genesis, Morphology and Cartography): ROY SIMONSON, Soil Survey Division, Soil Conservation Service, Washington, D. C.
Div. V-A (Forest and Range Soils): C. T. YOUNGBERG, Oregon State College, Corvallis, Oregon.
Div. VI (Soil Conservation, Drainage, Irrigation and Tillage): R. M. HAGAN, University of California, Davis, Calif.

CROP SCIENCE DIVISIONS, G. O. MOTT, vice-president and program chairman

Div. VII (Crop Breeding): K. J. FREY, Iowa State College, Ames, Iowa.
Div. VIII (Crop Physiology and Ecology): W. K. KENNEDY, Cornell University, Ithaca, N. Y.
Div. IX (Crop Production): M. A. HEIN, USDA Plant Industry Station, Beltsville, Md.

Div. X (Seed Production): S. R. ANDERSON, Ohio State University, Columbus, Ohio.
Div. XI (Turfgrass Management): C. G. WILSON, 815 Oeste Drive, Davis, California.
Div. XII (Weeds and Weed Control): R. J. ALDRICH, Rutgers University, New Brunswick, N. J.

AGRONOMIC EDUCATION DIVISION (XIII), DARREL METCALFE, Iowa State College, Ames, Iowa, vice chairman and program chairman.

(1) Resident Teaching section: J. K. PATTERSON, Washington State College.
(2) Extension section: V. P. OSTERLI, Univ. of California, Davis, Calif.
(3) Student Activities section: H. D. FOTH, Texas A&M, College Station, Texas.

CHARLES W. DOMBY DIES IN GEORGIA

CHARLES W. DOMBY, soil scientist at the Georgia Experiment Station, died shortly before Christmas in Athens, Ga., following an illness. Dr. Domby was born in Birmingham, Ala., March 29, 1919. He received his B. S. degree from Colorado State College, M. S. from the University of Georgia, and the Ph. D. degree from Purdue University in 1953. During World War II, he served with the 5th Engineers Special Brigade which participated in the Normandy invasion. He is survived by his wife and two children.

W. M. JARDINE DIES IN TEXAS

W. M. JARDINE, 76, former president and honorary life-time member of the American Society of Agronomy, and secretary of agriculture in the Coolidge administration, 1924–1928, died Jan. 17 in San Antonio, Tex. Dr. Jardine was president of the Society in 1917. At that time he was director of the Kansas Agricultural Experiment Station. He was later president of the college.

His brother, James T. Jardine, former director of research of USDA, died Oct. 24. J. T. Jardine was head of the Oregon Agricultural Experiment Station in 1920, and became chief of the USDA office of experiment stations in 1930.

SEVENTH INTERNATIONAL GRASSLAND CONGRESS

The Seventh International Grassland Congress will be held at Massey Agricultural College, Palmerston North, New Zealand, during the second week of November 1956. It will last for one week and will be followed by post-conference tours in both the North and South Islands.

The Congress program comprises 12 half-day sessions and 2 evening sessions. Each session will consist of a symposium of four papers dealing with a particular aspect of grassland problems and research.

Because the Congress is being held in New Zealand the program has been deliberately given a bias towards New Zealand grassland farming. Many of the sessions will, however, be dealing with subjects of a general nature and an endeavor is being made to secure as authors of papers leading grassland research workers of the world.

Papers will be of a technical nature and will deal mainly with the results of research into problems and practices of grassland farming. Particular emphasis is being laid on the pasture-animal complex.

Inquiries should be addressed to the Organising Secretary, Seventh International Grassland Congress, P. O. Box 2298, Wellington, New Zealand.

ICIA ACCEPTS NEVADA DEPARTMENT

The International Crop Improvement Association accepted the application for membership from the Nevada Department of Agriculture during the association annual meeting Nov. 8 to 11 at Toronto, Canada.

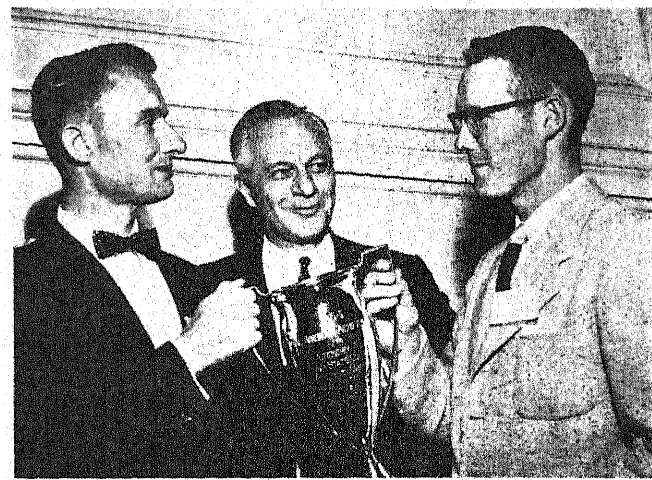
More than 200 delegates attended the meeting which was climaxed by a visit to the Royal Agricultural Winter Fair. Nations represented were the U. S., (36 states and Alaska), Canada, Denmark, England, Italy and Sweden.

Among special guests were ARNE KJAIER, seed production specialist with the Food and Agriculture Organization, Rome, Italy, and Dean FRANK J. WELCH of the University of Kentucky.

The 1955 annual meeting of ICIA will be held at the Casablanca hotel, Miami Beach, Fla., Nov. 8 to 11.

According to R. H. GARRISON, ICIA vice president, membership in the ICIA now stands as follows:

1 Alaskan certifying agency; 41 U. S. state certifying agencies, and 2 Canadian certifying agencies.



The Agronomy Club of Iowa State College was named the best student agronomy organization of its kind in the United States and winner of a trophy and $100 presented by the American Plant Food Council. The club received the National Agronomy Achievement Award for 1954 at the annual meeting of the American Society of Agronomy at St. Paul, Minn., in November.

Shown above, Willard H. Garman, Council Agronomist (left), is presenting the trophy to Iowa State College Agronomy Club President Galen Rozeboom (extreme right) as W. H. Pierre, head of the department of agronomy at Iowa State College, looks on.

MINNESOTA YOUTH IS PRESIDENT OF STUDENT AGRONOMISTS' GROUP

LESTER SCHMIDT, University of Minnesota student, was elected president of the student subdivision of the American Society of Agronomy during the 1954 meetings of the organization at St. Paul, Minn.

Other new officers of the group are: BOYD STUHR, University of Nebraska, vice-president; KENNETH MUNKRES, Kansas State College, recording secretary; JAMES HASENBECK, Oklahoma A&M College, corresponding secretary; and JACK McDANIEL, University of Arkansas, treasurer.

Retiring officers were: TEX AXLAND, Iowa State College, president; DAVID WARD, Tennessee A and I State University, vice president; MAYNARD KING, Cornell University, recording secretary; RICHARD HUMPHREYS, Oklahoma A and M, corresponding secretary; and DALE NITZEL, University of Nebraska, treasurer.

COMPACTION COMMITTEE APPOINTED

M. B. RUSSELL, president of the Soil Science Society of America, has appointed the following as a committee to study the problems of soil compaction:

W. H. ALLAWAY, A. A. KLINGEBIEL and P. J. ZWERMAN. They will work jointly with a similar committee appointed by the Agricultural Engineering Society.

FOREST SCIENCE JOURNAL APPEARS

The first issue of FOREST SCIENCE, an international Journal of research and technical progress in forestry, will appear in March, according to the chairman of its editorial board, S. H. SPURR, University of Michigan professor of silviculture. A cooperative venture of the Society of American Foresters and other forest research and educational groups, the quarterly journal will publish articles on research, teaching and administration.

AID FOR CHINESE REFUGEES

Under provisions of the 1953 Refugee Relief Act, the Aid Chinese Intellectuals, Inc., 1790 Broadway, New York City, has begun a program of helping anti-communist refugee Chinese enter the United States. According to FREDERIC LECLERCQ, director of the group's resettlement services, many of the registrants are highly qualified agronomists—both crops and soil scientists. Many have been trained in U. S. institutions. Departments, agencies or private firms in a position to employ such personnel may list their available positions with the organization at the above address.

MICHIGAN STATE COLLEGE SPONSORS CENTENNIAL NUTRITION SYMPOSIUM

The School of Agriculture of Michigan State College is sponsoring a centennial symposium, "Nutrition of Plants, Animals, and Man" Feb. 14 to 16. It is one of the commemorative events of the college's centennial year. Off-campus speakers include L. A. MAYNARD, Cornell University; A. G. NORMAN, University of Michigan; K. C. BEESON, USDA; W. A. ALBRECHT, University of Missouri; Dean E. N. TODHUNTER, University of Alabama; W. J. DARBY, Vanderbilt University; L. E. CLIFCORN, Continental Can Co.: A. B. KEYS, University of Minnesota and O. V. WELLS, USDA.

TWO CHANGES AT NORTH CAROLINA STATE COLLEGE

R. W. CUMMINGS, director of research at North Carolina State College, started a 2-year leave of absence Dec. 1 to serve as project director of a technical assistance research program with the Foreign Operations Administration in Peru. In his absence, R. L. LOVVORN will serve as acting director of research. He has been director of instruction since September 1953.

SUMMER STATISTICS SESSION AT FLORIDA

The second cooperative summer session in statistics will be held June 20 to July 29 at the University of Florida, Gainesville. The first such session, sponsored by the University of Florida, North Carolina State College, Virginia Polytechnic Institute and the Southern Regional Education Board was held in 1954 at North Carolina State College. The 1956 session will meet there again, and the 1957 session at Virginia Polytechnic Institute. The total tuition fee is $35. Holders of doctorate degrees may register without payment of tuition fee. Inquiries should be addressed to HERBERT A. MEYER, statistical laboratory, University of Florida, Gainesville, Fla.

FERGUS NAMED 'MAN OF YEAR'

E. N. FERGUS, for 35 years a member of the faculty of the University of Kentucky College of Agriculture, was named "Man of the Year" Nov. 29 at a meeting of the Southern Seedsmen's Association in New Orleans. He is widely known for his work with grasses and legumes, including Kenland clover, Ky. 31 fescue and other forage crops. He has been in charge of forage research since 1936, and at present is head of the Crops section of the agronomy department. He is a past chairman of the Agronomy Section of the Association of Southern Agricultural Workers and has served on the board of directors of the American Society of Agronomy.

NEWS ITEMS

W. H. ALDERMAN, retired head of the horticultural department, University of Minnesota, has received the Wilder medal from the American Pomological Society. He recently returned from the University of Salonika in Greece where he served as Fulbright professor.

—A—

EDWARD J. PEDERSEN, was transferred recently from his position as soil surveyor, SCS, for the northern Illinois area to Beltsville, Md., where he now has the position of soil chemist. From September 1953 to June 1954 he had been on leave from the SCS doing graduate work at the University of Wisconsin.

—A—

T. J. STAFFORD, formerly with the University of Georgia, is now in charge of outfield sugarcane investigations at the Louisiana Agricultural Experiment Station. His work involves determining the adaptability of newly released varieties to various soil types throughout the sugarcane belt.

—A—

CLINTON A. MOGEN, senior soil correlator, SCS, is now stationed at North Dakota State College, Fargo, serving the area of North Dakota and Montana.

—A—

N. K. ANANT RAO, professor and head of the agronomy department, Balwant Rajput College, Agra, India, is with the Farm Crops department, Rutgers University, New Brunswick, N. J., as a visiting professor on a Fulbright travel grant.

—A—

ILEY E. STOKES, recently superintendent of the U. S. Sugar Crops Field Station, Meridian, Miss., has been transferred to the Plant Industry Station at Beltsville, Md., where he will become project leader for sugarcane and sugar sorghum research in the Sugar Crops Section.

—A—

P. C. SANDAL, formerly assistant agronomist at the University of Arkansas, has been associate agronomist at North Dakota State College since Sept. 1. He is in charge of sweetclover and sudangrass breeding, and is also teaching genetics and plant breeding. At Arkansas he was in charge of alfalfa and lespedeza breeding and pasture research, and taught classes in forage crops, genetics and plant breeding.

—A—

A. L. BAKKE, Iowa State College botanist, received the most distinguished service award of the North Central Weed Control Conference for 1954. He was awarded a life membership in the Conference.

—A—

T. J. ARMY, who recently completed his doctorate work at North Carolina State College, is now stationed at Bozeman, Mont., with the Western Section of the Soil and Water Conservation Research Branch, USDA. His investigations are mainly concerned with soil and management problems in dry land agriculture.

—A—

DAVID PRAMER has been assistant professor and assistant research specialist in microbiology at Rutgers University since his appointment July 1. His interests are primarily with soil microbiology. He received his doctorate from Rutgers in 1952 after earlier studies at St. Johns University and Texas A and M College. During 1952 and 1953 he was a visiting research worker at the Butterwick Research Laboratories of the Imperial Chemical Industries.

—A—

EDWARD A. ANDREWS began work Jan. 1 as an assistant professor of plant pathology in the agronomy department at the University of Wyoming. He had been extension pathologist at Michigan State College since 1948. He replaces H. J. WALTERS who is now at the University of Arkansas.

—A—

WILLIAM D. KEMPER, who recently completed his Ph.D. degree at North Carolina State College, is now assistant agronomist (soils) at the Colorado Agricultural Experiment Station, and soil scientist for the Soil and Water Conservation Research Branch, ARS, USDA, at Fort Collins, Colo. He is conducting research in soils physics, and is on the graduate school faculty.

—A—

JOHN W. SCHMIDT has been directing state wheat and oat breeding projects at the University of Nebraska since Nov. 1. He succeeds V. A. JOHNSON who has become regional coordinator for hard red winter wheat investigations. Prof. Schmidt had been at Kansas State College since July 1951 where he had done work in wheat genetics, principally in monosomic analysis and Agrotricum hybridization.

PERSONNEL SERVICE

The Personnel Service column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of $2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a key number which will be carried for five additional insertions unless a discontinue order is received. Items pertaining to soils positions will be inserted one time in the *Soil Science Society of America Proceedings* unless otherwise specified. The following insertions, published in earlier issues, are still available: 8–1, 9–2, 11–1, 11–2, 12–1.

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AGRONOMY JOURNAL

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AGRONOMY JOURNAL

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The Effect of Clipping, Nitrogen Application, and Weather on the Productivity of Fall Sown Oats, Ryegrass and Crimson Clover[1]

L. V. Crowder, O. E. Sell, and E. M. Parker[2]

THERE has been an increased reliance on winter grazing as a source of feed during the winter months in the southeastern United States. It has been found that high production and dependability of winter pastures are influenced by factors such as date of planting, fertilization, rainfall, temperature, and diseases (3, 4, 5, 10). Burton, *et al.* (3) reported that winter pasture crops differed in the production of fall forage, and that by rotationally grazing several crops, an adequate supply of pasturage could be maintained. However, since many farmers rely on one winter grazing crop or mixture, it is necessary to secure maximum production on a small acreage. As a means of conserving winter pasturage, it has been suggested that forage growth be allowed to accumulate prior to cold weather and that grazing be regulated during the winter months (3, 5, 10).

Extensive investigations have been conducted concerning the effects of rotational grazing and frequency of clipping of permanent pasture plants on animal and forage production. Conflicting results have been reported, but usually rotational rather than continuous grazing has resulted in the maintenance of higher quality forage and improved animal performance (4, 6, 9, 13). Frequent removal of foliage has resulted in a reduction of root and forage growth and a decrease in the amount of lignin and fiber fractions, but the nitrogen, ether extract, ash, calcium, and phosphorus contents of the plant have been higher with such management. (1, 2, 4, 6, 7, 8, 9, 11 12).

Experiments herein reported concerned the effects of weather, frequency of clipping and applications of nitrogen on the productivity of a mixture of fall sown oats, ryegrass, and crimson clover. Such a mixture is suitable for fall and winter grazing. It was anticipated that the results of this investigation could be used as an aid in planning a management system for temporary winter pastures.

MATERIALS AND METHODS

In mid-September of 1947, 1948, and 1949 a winter pasture mixture consisting of 3 bushels per acre of Arlington oats, 15 pounds of domestic ryegrass, and 15 pounds of Dixie crimson clover was sown on a Davidson clay loam soil at Experiment, Ga. A uniform application of 600 pounds per acre of 10–10–10 fertilizer was made to the entire plot area before sowing. The oats were sown with a grain drill, and the ryegrass and crimson clover were broadcast with a cyclone seeder. The area was cultipacked. Three forage clipping frequencies and three nitrogen top dressing treatments were arranged over this planting in a randomized block design with four replications. The clipping frequencies were spaced at 2-, 4-, and 8-week intervals. The nitrogen top dressing rates were 16, 32, and 48 pounds per acre of nitrogen. Nitrogen applications were made each month, beginning in October and continued for 6 months.

Clippings were begun in November when the forage was approximately 10 inches high, and were repeated at 2-, 4-, and 8-week intervals. A sickle-bar mower was used to cut a 3-foot swath through the center of the plots which were 6 by 25 feet in size. The green weight of the forage from each plot was recorded, and a sample was taken for dry weight determination. Dry forage from each treatment was analyzed for protein; for the first year calcium and phosphorus determinations were made.[3]

Forage accumulations have been reported on a bi-monthly basis since it was found that these data were more closely correlated with the weather data, and since the data from the 8-week clipping interval fit this classification. Forage production for each bi-monthly period was correlated with the following weather data for the same period: rainfall, sunshine (recorded as gram calories per square cm. on a horizontal surface), and temperature (number of hours per bi-monthly period above 45° F). Simple correlations were made between forage yields and each weather variable, using the total bi-monthly dry forage accumulations from each treatment for each of the 3 years. The effect of each weather variable was determined by use of partial correlations.

RESULTS AND DISCUSSION

Effect of Clipping Interval on Bi-monthly Forage Yield

During the fall and early winter growth period (November–December clipping period) the forage yields for the 2- and 4-week clipping treatment were variable from year to year but the difference between them was not significant. The 8-week clipping treatment resulted in approximately 60% more forage during the fall of 1947 and 1948 than the 2- and 4-week intervals. Production resulting from the clipping treatments was not different in the fall of 1949 and probably resulted from low and irregular rainfall from September through December. The trend of production during the fall and early winter is illustrated by the November–December harvest data shown in table 1. Yields ranged from 500 to 1,500 pounds of dry matter per acre. Since little difference occurred between the 2- and 4-week clipping interval, these data might indicate that continuous or short rotational grazing of a temporary winter pasture mixture such as oats-ryegrass-crimson clover could be practiced in the fall.

Rate of growth during January and February was favored by the extended clipping intervals. The 8-week clipping resulted in 50 and 100% more forage than the 4- and 2-week clipping intervals, being 1,645, 1,090, and 800 pounds per acre, respectively (table 1). These results suggest that temporary winter pastures should be grazed less

[1] Journal Series No. 268, Georgia Experiment Station, Experiment, Ga. Rec. for publication July 12, 1954.

[2] Associate Agronomist; Head, Animal Industry Dept., and Assistant Agronomist, Georgia Agr. Exp. Sta., the latter now with Spencer Chemical Co.

[3] Chemical analyses were made by the late T. C. Dulin, Assistant Chemist, Georgia Exp. Sta. who used official AOAC methods.

Table 1.—Dry forage production of an oats-ryegrass-crimson clover mixture as influenced by clipping treatment.*

Clipping interval	Pounds of dry matter obtained			
	November-December	January-February	March-April	Total
2-week	730	800	1810	3340
4-week	820	1090	2660	4420
8-week	1025	1645	3540	6210
5% L.S.D.	111	109	174	291

* Clipping was begun in November and thereafter at the predetermined interval. Figures are 3-year averages of nitrogen treatments, 1947 to 1950.

intensely during the winter. A practical solution to the problem of maintenance of an adequate supply of winter pasturage would probably be to regulate grazing during the fall and winter; i.e., permit the animals to graze for several hours, then return them to a holding pasture.

Rapid plant growth usually began in late February so that production of all treatments was high during March and April (table 1). Forage yields were significantly increased during this period with extended clipping intervals but growth under the 2-week interval was sufficient to have permitted continuous grazing and heavy stocking rates in the spring.

Effect of Nitrogen Application on Forage Yield

The annual response to nitrogen was similar from year to year, there being no significant interaction with years or clipping treatment.

During the November–December growing period no increased response to monthly applications of 32 and 48 pounds per acre of nitrogen was obtained as compared to 16 pounds. However, forage returns were significantly increased by the two heavier rates during the January–February and March–April periods so that total dry matter accumulations were positively related to the amount of nitrogen applied (table 2). No doubt the heavier rains which fell during the winter and early spring resulted in leaching of the nitrogen from the soil so that a nitrogen effect was expressed by the higher rates of application. Monthly topdressings of nitrogen probably would not be economical but these data indicated that an additional winter topdressing may be needed to stimulate growth during warm winter periods.

Chemical Composition of the Forage

Chemical analyses showed that the herbage was high in protein and contained adequate phosphate and calcium for animal requirements. The crude protein content of the forage (dry basis) was as high as 35% in the fall and winter but decreased to 10% in the spring as the plants became mature (table 3). More detailed analyses indicated that the proportion of nitrate nitrogen found in winter pasture herbage which had above 30% crude protein approached a danger level during midwinter. During periods of slow plant growth (low forage yields) amounts up to 0.6 of one percent were found in forage removed in January and February from the plots being clipped each 2 weeks and receiving 48 pounds of nitrogen per month. Delay in clipping resulted in a sward which was lower in nitrogen content, the clipping effect being more evident in late winter and spring. Monthly applications of 32 and 48 pounds per acre of nitrogen resulted in a slight increase in the protein content of the forage as compared to the 16-pound treatment but the difference was not as pronounced as the effect of the more frequent clipping versus the delayed clipping treatment.

The amount of phosphorus in the forage was found to be above 0.70, 0.95, and 0.80% for the November–December, January–February and March–April periods, respectively. For the same periods the calcium content averaged 0.45, 0.53 and 0.46%. Delayed clipping resulted in a slight decrease in the amount of phosphorus and calcium in the herbage at each harvest date, while nitrogen applications of more than 16 pounds per acre had no apparent effect on the percentage of these two minerals.

Table 2.—Effect of nitrogen application and clipping interval on the total dry forage produced by an oats-ryegrass-crimson clover mixture.

Clipping interval	Pounds per acre of dry matter when topdressed with the following amounts of N per acre*		
	16	32	48
2-week	2830	3220	3960
4-week	3900	4200	4850
8-week	5810	6075	6715

* Nitrogen was applied each month, beginning in October and continuing for 6 months. Figures are 3-year averages, 1947 to 1950.

Table 3.—Crude protein of oats-ryegrass-crimson clover forage as influenced by clipping frequency.

Clipping interval	Percentage crude protein for bi-monthly periods*		
	November-December	January-February	March-April
2-week	28.44	29.55	22.00
4-week	28.11	27.66	17.44
8-week	26.77	21.66	10.11
5% L.S.D.	1.71	3.83	4.28

* Average of 3 N treatments, 1947 to 1950.

Table 4.—Weather data and dry forage yields for bi-monthly periods.

Period	Dry forage lbs acre	Hrs. per month above 45° F.	Rainfall inches	Sunshine gm. cal cm^{2}
Nov.–Dec., 1947	610	997	12.3	11,000
Nov.–Dec., 1948	1440	1351	18.9	11,400
Nov.–Dec., 1949	300	1161	5.0	12,300
Jan.–Feb., 1948	700	820	9.8	13,500
Jan.–Feb., 1949	1310	1303	7.6	14,400
Jan.–Feb., 1950	1960	1330	5.7	15,200
Mar.–Apr., 1948	3110	1363	11.8	25,900
Mar.–Apr., 1949	2750	1299	9.4	25,400
Mar.–Apr., 1950	2170	1166	7.5	29,000

* Dry forage figures are averages for clipping and nitrogen treatments.

Botanical Composition of Forage

Forage harvested in November was about 95% oats. During December through February the ryegrass made sufficient growth to contribute 50% of the pasturage. Crimson clover added very little to the herbage content until late winter, and then only on plots clipped every 8 weeks and top-dressed with 16 pounds of nitrogen. The more frequent clipping and higher nitrogen applications stimulated tillering and growth of the grass and apparently suppressed clover growth. From counts made in January of each year it was found that shoots per plant of oats and ryegrass averaged 30% lower with each delayed clipping interval, but were increased about 15% with each increment of nitrogen. Tillering averaged 5.5, 3.6, and 2.7 shoots per plant for the 2-, 4-, and 8-week clipping intervals, and 2.6, 3.5, and 4.0 for the 16, 32, and 48 pounds per acre of nitrogen treatments, respectively.

Weather Date and Forage Yields

During the fall and early winter, forage growth varied significantly from year to year. It was apparent that germination and the accumulation of dry matter in September, October, and November, when the plants were being established, were dependent to a great extent on rainfall during the same period. Rainfall for the 3 months, September through November, was 10.8, 19.6, and 6.0 inches for 1947, 1948 and 1949, respectively. Dry matter harvested in November for each of the 3 years averaged 450, 950, and 150 pounds per acre ($r = 0.96$ for the variables rainfall and forage yield). Past weather records showed that in most of the southeastern United States these 3 months constitute the period of least rainfall for the entire year. This is the time for establishment of many permanent pasture crops and particularly temporary winter grazing crops. A survey of weather records disclosed that in the Georgia Piedmont, 14 of the past 30 years had an average of less than 0.25 of an inch and 18 of 30 years had less than 0.50 of an inch of rainfall per week from September through November. Thus, pasture establishment and early winter forage production may be limited and somewhat hazardous in some areas of the Southeast. However, early seedbed preparation, using methods which aid in conserving soil moisture, can obviate these hazards to some extent.

Average or more rain fell during the other periods of the growing season except for November and December in 1949, when it amounted to only 5 inches (table 4). A high correlation value (0.96) existed between rainfall and the amount of forage harvested during the November–December and March–April periods. Partial correlations disclosed that rainfall and temperature were interrelated during the period from planting through November, but their influence on forage growth was independent during the November–December harvest period. Rainfall was not a factor which affected production during the January–February period.

Heavy rainfall usually occurs throughout the Southeast from December through February. If adequate stands are present and plant nutrients are not limiting factors, data from the present experiment indicate that plant growth during the winter will probably be dependent on the temperature and solar radiation. The number of hours with temperatures above 45° F. was found to be more closely correlated with forage production than the number of hours above any other temperature. This finding that temperature affected plant growth processes appears to be in accordance with Blackman's (2) report that uptake of nitrogen by cereals was higher at 45° F. than at lower temperatures.

Correlation values of 0.75, 0.89, and 0.98 were found for forage yields and temperatures during the November–December, January–February, and March–April harvest periods, respectively. From partial correlation values, it appeared that the number of hours above 45° F. during January and February was dependent on the amount of solar radiation. No relationship existed between the two for the other periods. The number of hours above 45° F. varied from year to year (table 4) and from month to month. Within the growing season the temperature rose above 45° F. for only a few hours per day, or for a continuous period of several days—at times for longer than a week. Forage harvested during January and February of 1949 and 1950 averaged from ½ to 1 ton of dry matter per acre when the temperature remained above 45° F. for 85% of the time (1,300 hours). On the other hand, less than 1/3 ton of pasturage was available when the temperature remained above 45° F. for 800 hours, or 55% of the period (table 4). If it can be assumed that temperatures above 45° F. for at least 500 hours per month are necessary to permit sufficient growth to supply adequate grazing, then it is likely, from past weather data, that 1 out of 2 years will be warm enough to permit growth for grazing during the winter.

The amount of sunshine as measured in gm. cal/cm.^{2} was lower during November–December than the other periods (table 4). However, it was only during the January–February period that sunlight was significantly correlated with forage production (0.98). This relationship was not a simple light effect since partial correlation valves showed that temperature and light were interrelated.

CONCLUSIONS

A mixture of Arlington oats, domestic ryegrass, and Dixie crimson clover was sown in plots at Experiment, Georgia, in mid-September of 1947, 1948, and 1949. Beginning in October and continuing for 6 months the plots were top-dressed with monthly applications of 16, 32, and 48 pounds of nitrogen per acre. Clipping was begun in November and spaced at intervals of 2, 4, and 8 weeks.

Dry matter yields were greatest with the longest interval between clippings (the 8-week treatment). Little difference in productivity occurred between the 2- and 4-week intervals during the fall. However, the 4-week clipping treatment resulted in more forage production during the winter and spring than did the 2-week interval. These results indicate that regulated or rotational grazing should be practiced, particularly in the fall and early winter when growth is largely dependent on rainfall and temperature.

Monthly nitrogen top-dressing applications did not alter the forage yields during the fall and early winter. However, the production of dry matter in late winter and early spring was increased as the increments of nitrogen application were raised from 16 to 32 and 48 pounds per acre.

The protein content of the forage was relatively high throughout the season, being about 28% on a dry basis in the fall and winter and from 10 to 20% in the spring. Delayed clipping had a depressing effect on the nitrogen content of the forage.

Significant correlations existed for yields of dry matter during the periods of November–December and March–April and the two variables—rainfall and the number of hours per month above 45° F. Correlation values indicated that

the amount of growth during January and February was dependent on the temperature and solar radiation.

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Results From Uniform Winter Hardiness Nurseries of Oats For the Five Years 1947 to 1951, Inclusive[1]

Franklin A. Coffman[2]

THE cooperative uniform winter hardiness nurseries have now been grown for 25 years. Results for the periods 1927 to 1936, 1937 to 1941, and 1942 to 1946 have been published (2, 3, 4, 5, 6, 10). This paper reports data obtained on experiments grown during the period 1947 to 1951, inclusive, bringing results up to date. During the 5-year period 1947 to 1951, winter killing of a differential nature was reported in 148 of the 228 nurseries sown.

EXPERIMENTAL PROCEDURE

The experiments were conducted during this 5-year period by the same general plan as was followed during the previous 10 years. On the stations in the South where little killing occurs, all oats were seeded in duplicate rows, 50 kernels per row; whereas on stations located farther north where winterkilling is frequently reported, each entry was seeded in duplicate 5-foot rows, with 5 gm. of seed per row. In the former, the survival percentages are based on actual counts in the fall and in the spring, whereas in the latter nurseries survival percentages were based on estimated stands in the fall and spring.

It would seem reasonable that actual counts would tend to disclose small differences that could otherwise be overlooked. Also, in the South where growth in oats is continuous throughout the winter, differences in growth rate could easily be mistaken for differences in hardiness; however, a comparison of the data obtained from all stations indicates little or no difference in the relative survival of the same varieties as a result of the differences in the type of nursery planting and method of determining survival.

States and stations cooperating during the past 5-year period are in general the same as cooperated in the previous 5-year period. Whereas a few stations have discontinued cooperation in these experiments, others have joined in the cooperative effort, so that in recent years some 45 stations have grown the nursery each year.[3, 4]

During the 5 years a sufficiently large number of cooperators grew the nursery each season to supply ample data for determining rather accurately the relative hardiness of a large number of new oats even when included for only one or two seasons. One of the valued results of this experiment is that the relative hardi-

[1] Contribution from the Field Crops Research Branch, Agricultural Research Service, U.S.D.A. Received for publication July 29, 1954.

[2] Senior Agronomist. Acknowledgement is hereby made for assistance from all the cooperators, shown in footnote 3, who supplied data on the respective hardiness nurseries.

[3] Cooperators contributing data for the summary included in table 1 herein were: C. Roy Adair; I. M. Atkins; E. C. Bashaw; D. H. Bowman; Acton Brown; R. M. Caldwell; R. S. Cathcart; W. H. Chapman; H. R. Clapp; F. A. Coffman; L. E. Compton; R. G. Dahms; Geo. H. Dungan; Verne Finkner; P. T. Gish; U. R. Gore; John Gray; John M. Green; P. W. Gull; S. J. Hadden; E. E. Hall; N. I. Hancock; T. T. Hebert; J. W. Hendricks; J. A. Hendrix; D. R. Hooten; S. S. Ivanoff; D. M. Johns; T. H. Johnson; L. M. Josephson; B. M. King; C. A. Lamb; Harold Loden; E. S. McFadden; G. K. Middleton; Darrell Morey; J. Y. Oakes; J. Fred O'Kelly; W. M. Osborn; W. R. Paden; J. W. Pendleton; J. M. Poehlman; Kenneth Porter; D. A. Reid; B. G. Rothgeb; Blair C. Ritter; G. W. Rivers; A. M. Schlehuber; Edward Shulkcum; Robt. S. Snell; T. M. Starling; J. W. Taylor; Collins Veatch; Henry W. Webb; Geo. J. Wilds; W. J. Wiser; and Harold F. Yates.

[4] The states, number of locations, and reports per state were as follows: Ala., 1, 3; Ark., 2, 10; Fla., 1, 4; Ga., 3, 13; Ind., 4, 13; Ill., 2, 9; Ky., 3, 10; La., 5, 11; Md., 2, 10; Miss., 3, 15; Mo., 4, 12; N. J., 1, 5; N. C., 2, 10; Ohio, 3, 7; Okla., 4, 15; S. C., 6, 20; Tenn., 5, 17; Tex., 5, 19; Va., 2, 10; W. Va., 3, 11.

Table 1.—Summarized annual percentage survivals of winter oat varieties and selections and average survivals compared with that of the Winter Turf variety.

Variety or selection	C. I. No.	1947 (39 Stations)	1948 (29 Stations)	1949 (30 Stations)	1950 (22 Stations)	1951 (28 Stations)	Weighted average survival: Variety	Weighted average survival: Winter Turf (same tests)	Weighted average survival: Percentage Winter Turf 1947–51	No. of tests 1947–51
		Red Rustproof and Red Rustproof Hybrids								
Appler	1815	42.3	57.6	54.0	58.7	27.0	47.2	69.3	68.1	148
Carolina Red	4313	56.2	60.6	56.5	64.2	23.9	52.2	69.3	75.3	148
Carolina Red: Marretts Strain 2	5365	—	—	—	63.7	—	63.7	75.1	84.8	22
Red Rustproof × Bond: Fla. 40–10–15–9–3–1–2	4827	—	32.1	—	—	—	32.1	80.2	40.0	29
Red Rustproof²* × (Victoria–Richland)	4386	33.9	—	—	—	—	33.9	69.6	48.7	39
Red Rustproof²* × (Victoria–Richland)	4661	34.8	57.1	—	—	—	44.3	74.1	59.8	58
Red Rustproof²* × (Victoria–Richland)	4662	34.5	—	—	—	—	34.5	69.6	49.6	39
Red Rustproof × (Victoria–Richland) × Fultex	5352	—	—	—	—	26.1	26.1	50.4	51.8	28
Red Rustproof²* × Victoria–Richland × (Fulwin × Lee–Victoria)	4835	—	64.9	55.4	—	—	60.1	75.8	79.3	59
		Fulghum and Fulghum Hybrids								
Fulghum	708	45.1	60.6	48.5	61.8	26.3	47.8	69.3	68.9	148
Pentagon (Fulghum, Winter Type)	2499	76.2	86.6	74.2	85.5	73.0	78.6	69.3	113.4	148
Fulghum (Ky. Sel. 45–79)	5108	—	—	75.1	82.1	—	78.1	73.1	106.8	52
Fulwin	3168	80.3	89.9	74.6	73.0	70.4	78.1	69.3	112.7	148
Fultex	3531	55.7	58.6	47.7	65.2	33.0	51.8	69.3	74.4	148
(Iogold–Bond) × Fultex	4656	29.3	—	—	—	—	29.3	69.6	42.1	39
Woodward Sel. 472606	5106	—	—	—	81.9	74.3	77.6	74.7	103.8	50
Fulgrain: Cokers 45–13456	4655	39.7	—	—	—	—	39.7	69.6	57.0	39
Fulgrain: Cokers '48 Breeders Stock	4831	—	57.5	—	—	—	57.5	80.2	71.7	29
Fulgrain: Cokers '49 Breeders Stock	5115	—	—	50.5	—	—	50.5	71.6	70.5	30
Fulgrain: Cokers '50 Breeders Stock	5356	—	—	—	60.5	—	60.5	75.1	80.6	22
Fulgrain: Cokers '51 Breeders Stock	5847	—	—	—	—	30.0	30.0	50.4	59.5	28
Victorgrain: Cokers 45–3	4557	41.4	—	—	—	—	41.4	69.6	59.5	39
Victorgrain: Cokers '48 Breeders Stock	4832	—	66.6	—	—	—	66.6	80.2	83.0	29
Victorgrain: Cokers '49 Breeders Stock	5114	—	—	50.5	—	—	50.5	71.6	70.5	30
Victorgrain: Cokers '50 Breeders Stock	5353	—	—	—	58.0	—	58.0	75.1	77.3	22
Victorgrain: Cokers '51 Breeders Stock (Cokers 48-93)	5355	—	—	—	—	41.3	41.3	50.4	81.9	28
Anderson: Marretts No. 1	4651	48.0	72.0	60.6	—	—	59.0	73.3	80.5	88
Anderson: Marretts 10111	5121	—	—	—	67.2	—	67.2	75.1	89.5	22
Bulk Winter Oat: (Fulton–Clinton × Wintok)	5367	—	—	—	74.8	—	74.8	75.1	99.6	22
Victoria × (Hajira–Banner) × Fulghum–Victoria × 73–44–90	5371	—	—	—	44.1	—	44.1	75.1	58.7	22
		Bond Hybrids†								
Delair: Fulghum (HC726) × Bond sel. 4076–1	4653	41.0	60.0	—	—	—	49.1	74.1	66.4	58
Taggart: Fulghum (HC726) × Bond sel. 4076-16	4652	53.2	62.4	—	—	—	57.1	74.1	77.1	58
Cokers Full Bright	5126	—	—	—	33.1	—	33.1	75.1	44.1	22
LeConte: (Tenn. 1884 × Bond)	5107	—	—	75.8	77.5	56.6	69.5	65.1	106.8	80
Fulwin × Lee–Victoria × Bonda	5380	—	—	—	—	30.0	30.0	50.4	59.5	28
Fulwin × Lee-Victoria × Bonda	5381	—	—	—	—	35.8	35.8	50.4	71.0	28
Clinton × Hairy Culberson: Ind. 407–26–6	5368	—	—	—	85.4	61.3	71.9	61.3	117.2	50
Clinton × Forkedeer: Ind. 4011–4–5–3	5369	—	—	—	84.8	58.2	69.9	61.3	114.0	50
(D69–Bond) × Fultex: Tex. Sel. 64–44–61	5370	—	—	—	51.0	—	51.0	75.1	67.9	22
Tenn. 1922 × (Iogold–Bond): Cokers 45–67	4833	—	72.7	65.7	—	—	69.1	75.8	91.2	59
Fulwin × (Victoria × Hajira–Banner): Tex. 152–44–280	5109	—	—	62.1	—	—	62.1	71.6	86.7	30
Fulwin × (Victoria × Hajira–Banner): Tex. 152–44–283	5111	—	—	60.5	—	—	60.5	71.6	84.5	30
(Fulwin–Tennex) × Bond: Tex. Sel. 152–44–4	4834	—	83.1	74.4	79.8	42.9	69.7	69.1	100.9	109
Fulwin × (Victoria × Hajira–Banner): Tex. 152–44 122	5112	—	—	60.3	—	—	60.3	71.6	84.2	30
Tennex × (Victoria × Hajira–Banner): Tex. 125–44–204	5113	—	—	60.7	—	—	60.7	71.6	84.8	30
		Black Winter								
Tech: V. P. I. No. 1	947	76.4	85.1	77.2	81.0	63.8	76.6	69.3	110.5	148

Table 1.—(Continued).

Variety or selection	C. I. No.	1947 (39 Stations)	1948 (29 Stations)	1949 (30 Stations)	1950 (22 Stations)	1951 (28 Stations)	Weighted average survival: Variety	Weighted average survival: Winter Turf (same tests)	Weighted average survival: Percentage Winter Turf 1947-51	No. of tests 1947-51
		Culberson and Culberson Hybrids								
Hairy Culberson	2505	78.8	91.6	67.4	78.0	63.3	75.9	69.3	109.5	148
Bicknell	3218	79.5	86.3	76.0	80.1	67.3	77.9	69.3	112.4	148
Wintok: (Hairy Culberson × Fulghum C. I. 2500)	3424	85.0	93.8	76.6	88.4	80.3	84.6	69.3	122.1	148
Wintok: Okla. Sel. 492825	5849	—	—	—	—	78.5	78.5	50.4	155.8	28
Woodward Composite Sel. 3527-43-3	4828	—	91.6	71.5	—	—	81.4	75.8	107.4	59
Colo × Wintok: (Hancock × Morota-Bond) × Wintok	4663	67.9	85.1	70.8	—	—	73.9	73.3	100.8	88
Colo × Wintok: (Hancock × Morota-Bond) × Wintok	5118	—	—	81.6	81.7	62.0	74.7	65.1	114.7	80
Colo × Wintok: (Hancock × Morota-Bond) × Wintok	5366	—	—	—	72.0	—	72.0	75.1	95.9	22
		Winter Turf and Winter Turf Hybrids								
Winter Turf (Check)	3296	69.6	80.2	71.6	75.1	50.4	69.3	69.3	100.0	148
Winter Turf × (Clinton ^{2} × Santa Fe)	5471	—	—	—	—	30.9	30.9	50.4	61.3	28
Cornell Sel. No. 1375	5364	—	—	—	—	75.4	75.4	50.4	149.6	28
		Lee and Lee Hybrids								
Lee	2042	67.6	83.0	68.9	74.5	45.8	67.8	69.3	97.8	148
Lemont	4080	58.2	—	—	—	—	58.2	69.6	83.6	39
Letoria: Lee-Victoria	3392	66.0	81.7	62.8	76.5	48.9	66.8	69.3	96.4	148
Letoria: Ga. Sel. 6	4659	51.3	73.4	—	—	—	60.7	74.1	81.9	58
Stanton: Lee-Victoria Cokers '47 Breeders Stock	4654	65.3	—	—	—	—	65.3	69.6	93.8	39
Stanton: Lee-Victoria Cokers '48 Breeders Stock	4830	—	82.5	—	—	—	82.5	80.2	102.9	29
Mustang: Fulwin × (Lee-Victoria)	4660	72.1	85.9	63.7	79.5	52.5	70.5	69.3	101.7	148
(Lee-Victoria) × Fulwin	4658	55.5	—	—	—	—	55.5	69.6	79.7	39
Atlantic: (Lee-Victoria) × Fulwin	4599	69.4	80.3	—	—	—	74.0	74.1	100.1	58
Atlantic × (Clinton ^{2}-Santa Fe)	5497	—	—	—	—	27.7	27.7	50.4	55.0	28
Arlington: (Lee-Victoria) × Fulwin	4657	55.3	75.4	—	—	—	63.9	74.1	86.2	58
(Lee-Victoria) × Forkedeer: Ind. A392	5848	—	—	—	—	64.0	64.0	50.4	127.0	28
		Miscellaneous Hybrids								
Sturdy	5117	—	—	50.8	—	—	50.8	71.6	70.9	30

* Superscripts (in italics) indicate number of times recurrent variety was used as a parent.
† Selections from crosses that include Bond among oats from which they were derived and which appear to resemble their Bond parent a little more closely than any of their other parental types.

ness of a new oat grown in these nurseries can be determined rather accurately in a short time. Thus, oat breeders can quickly evaluate the hardiness of their new varieties.

RESULTS AND DISCUSSION

Table 1 lists the average survival of the 70 varieties and selections tested for 1 or more of the 5 years. Data are included from only nurseries in which differential killing was reported. No attempt is made to determine whether varieties respond differently at different stations on different soil types, or whether varieties differ in regional adaptation. Most of the 70 entries are of hybrid origin. Much of the oat breeding in the past 2 decades consisted of the incorporation of genes for disease resistance from *Avena byzantina* into *A. sativa;* consequently, many new strains are somewhat intermediate, but the 70 entries might be grouped roughly into about equal numbers of *A. byzantina* and *A. sativa* morphological types. In table 1, the strains are grouped according to the parental strain which they most closely resemble.

In a recent paper (5) it was indicated that Red Rustproof could be considered as an old oat type. It is suspected that oats of that type gave rise to such oats as Fulghum, Black Winter, Culberson, and Winter Turf.

During the 5-year period, 1947 to 1951 inclusive, winterkilling was severe in the less hardy entries in 1946–47 and 1948–49 and in all entries in 1950–51. Published reports (3, 4, 6) indicate that 1950–51, next to 1927–28, was one of the most severe seasons for winter oats throughout the quarter century of these experiments. The relative standing of survival percentages of the older entries has remained rather constant throughout the period. A few entries grown for short periods have given rather favorable survival records, but none of these has been grown sufficiently long for conclusive results. From the standpoint of hardiness the more promising new entries grown for only 1 or 2 years are C.I. Nos. 5368, 5369, 5849, 5118, 5364, and 5848. Several of these oats are from crosses made to combine disease resistance with winter-hardiness.

Eight entries were grown in all 25 years. Winter Turf (C.I.3296)[5] the standard check, has a weighted averaged survival of 69.5% in the 560 nurseries in which differential killing was reported. The average survival in consecutive 5-year periods was 57.3, 72.2, 71.4, 69.5, and 69.3%. In the 25 years the relative survival in percentage of that of Winter Turf was Bicknell, 108.8; Hairy Culberson, 108.5;

[5] C.I. refers to accession number of Section of Cereal Crops.

Pentagon, 107.2; Tech, 104.6; Lee, 97.6; Fulghum (C.I. 708), 83.6; and Appler, 81.0.

In experiments conducted for shorter periods, Wintok's (15) survival averaged 114.8% of that of Winter Turf in 233 comparisons; Fulwin (13), 111.4 in 274; Letoria (11, 12, 14), 99.9 in 222; Lemont (15), 91.3 in 31; Fultex (8, 11, 14), 81.7 in 197; and Carolina Red (8, 11, 14), 75.4 in 78 comparisons with Winter Turf.

Numerous attempts have been made to incorporate disease resistance into oats for fall seeding during the past 25 years. (1, 7, 8, 9, 11, 12) Progress has been made, but no very hardy oat carries resistance to more than one or two major disease organisms. Originally disease resistance was found almost exclusively in spring-type oats. Experience with spring-winter crosses has shown that hardiness is extremely difficult to obtain in the progeny, evidently because of multiple factors; however, in Letoria the hardiness of the Lee parent was recovered almost fully in this segregate of a Lee × Victoria cross (11, 12). Lee (15), the progeny of a Winter Turf × Aurora cross, has a survival record of 97.6% of Turf in 560 comparisons; whereas Letoria has a survival of 99.9% of Turf in 222 comparisons. Thus, the breeding of hardy, disease-resistant oats does not appear to be insurmountable.

SUMMARY

Five years' additional data from uniform hardiness oat nurseries substantiate results of the previous 20 years. Wintok appears to be the most winter-hardy variety, followed by Fulwin. Their survivals have been 114.8 and 111.4%, respectively, of Winter Turf check.

Obtaining oats having both hardiness and disease resistance is clearly difficult. Genes for disease resistance originally were located almost exclusively in spring-type oats; however, Letoria has survived as well as its more hardy parent and also is resistant to certain diseases.

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The Effect of Cultural Practices on Emergence and Uniformity of Stand of Sugar Beets[1]

I. M. Wofford and S. T. Dexter[2]

IMPROVEMENT of the rapidity, percentage and uniformity of sugar beet seedling emergence in the field is at present one of the most important needs in sugar beet production. The grower is well aware of a great deal more variation in rate and percentage emergence of sugar beets than of beans, corn, or small grains. In addition to the positive effect on beet yields, the improvement of seedling emergence in the field is necessary before complete spring mechanization can be accomplished.

REVIEW OF LITERATURE

Much work has been done on the relationship of tillage practices to seedling emergence and crop yields. Results of these experiments vary as to which method is considered best (5, 7, 12). Depth of planting was found by Hentschel[3] to have a greater effect upon emergence than did the method of fitting the seedbed and planting the seed. Barmington (1) found that highest emergence of beet seedlings was obtained when soil moisture and soil firmness were highest, and lowest when these factors were lowest. Cook (2, 3) reported that good stands and yields of sugar beets were obtained on plots where the soil had been plowed and fitted in one operation, and at all times through the growing season the crop looked best on those plots which had received

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[3] Hentschel, H. E. A study of principles affecting the performance of mechanical sugar beet seed planters. Unpublished M. S. thesis, Michigan State College, 1946.

the least pre-planting tillage. The literature on the subject of fall plowing versus spring plowing is controversial (4, 6, 8, 9, 13, 15).

Extensive research has been conducted to determine the influence of soil building or green manure crops upon succeeding crops. A complete discussion of various green manuring principles and practices with a comprehensive bibliography on the subject is presented by Pieters (10). Ripley (11) gives an extensive review of material on crop rotations and influences of crops upon those which follow. Skuderna and Johnson (14) report that where alfalfa is used in the rotation, the practice varies as to whether the first, second, or third growth is plowed under. The important thing is to turn down some top growth.

MATERIALS AND METHODS

A series of field experiments was set up to determine the response of sugar beets, particularly in regard to seedling emergence, to various methods of seedbed preparation and green manure crops.

Segmented sugar beet seeds of commercial varieties were planted with a commercial 4-row beet drill at the rate of 8 pounds per acre. Recommended rates and grades of fertilizer were used for all crops.

Experiment 1

A split plot experiment was conducted during the 1951–1952 season utilizing different tillage methods for incorporating green manure crops into the soil as the main treatment and different green manure crops and wheat straw mulch as the subtreatments.

The different tillage methods used to incorporate the green manure crops and wheat straw included, (a) disking the material to the extent that it was partly uncovered and partly just covered with soil, forming a "rough" seedbed; (b) disking the material into the top 3 to 5 inches of soil to give a "medium rough" seedbed; and (c) plowing the material under with a moldboard plow to form a "plowed" seedbed. One-third of each plot received one of these tillage treatments.

Stand counts of sugar beet seedlings were taken 3 weeks after planting (2 weeks after beets had started to emerge) on 10 feet of each of the 4 middle rows. The sugar beets were blocked and thinned by hand labor, then cultivated and hoed throughout the growing season to control weeds.

The 4 middle rows of each 6-row plot were harvested and the number and weight of marketable beets recorded.

Experiment 2

A field seeded to alfalfa in May 1950, from which two cuttings of hay were removed in 1951, was used for an experiment to determine the effects of, *(1)* various methods of handling the forage crop, and *(2)* different methods of land preparation or tillage treatments for planting sugar beets. The experiment, which was conducted during the 1952–1953 season, included 15 treatments, replicated 6 times, and arranged in a randomized block design. The treatments used in these tests were as follows:

One cutting of alfalfa (June 19), hay left on plots.

1. Fall plowed 1952.
2. Spring plowed 1953.
3. "Field cultivated" and planted to rye in fall 1952; rye "field cultivated" in spring 1953.
4. "Field cultivated" in fall 1952.
5. "Field cultivated" in spring 1953.

Three cuttings of alfalfa (June 19, Aug. 5, Sept. 16), all hay removed (to reduce stand and growth).

6. Spring plowed 1953.
7. "Field cultivated" in spring 1953.

Two cuttings of alfalfa (June 19, Aug. 5), all hay removed.

8. Fall plowed 1952.
9. Spring plowed 1953.
10. "Field cultivated" in spring 1953.

Two cuttings of alfalfa (June 19, Aug. 5), first cutting removed, second cutting left on plots.

11. Fall plowed 1952.
12. Spring plowed 1953.
13. "Field cultivated" and planted to rye in fall 1952; rye "field cultivated"in spring 1953.
14. "Field cultivated" in fall 1952.
15. "Field cultivated" in spring 1953.

Observations were made on the number of alfalfa plants remaining in each plot 1 month after planting sugar beets. At the same time notes were taken on the amount of weed growth in each plot. Visual vigor readings on sugar beet plants using an arbitrary standard were made when stand counts were taken, again just after blocking and thinning, and later mid-way of the growing season.

As a further measure of the effects of the different treatments, stand counts of sugar beet seedlings were taken on the 4 middle rows of each plot 1 week before blocking and thinning.

Experiment 3

A replicated split plot experiment was set up in the spring of 1953 to determine the effects of different tillage practices, as applied to seedbed preparation, on the emergence and uniformity of stand of sugar beet seedlings. The experiment, replicated 4 times, consisted of 8 row plots, 44 feet long, and set up on a sod field of red and ladino clover.

The four seedbed tillage treatments were as follows:

1. To prepare a loose-wet seedbed.—This method consisted of pulling a commercial Valley Clodbuster behind a moldboard plow to pulverize and moderately pack the soil before it dried out after plowing. Planting followed within an hour, to take advantage of the favorable moisture conditions which exist a short time after plowing.

2. To prepare a firm-wet seedbed.—This method consisted of plowing, followed by two double diskings and two harrowings with the spring-tooth and two harrowings with the spike-tooth harrow. Planting followed at once.

3. To prepare a firm-dry seedbed.—This treatment was the same as Treatment 2 above except planting was delayed 3 days.

4. To prepare a loose-dry seedbed.—The same operation as outlined in Treatment 1 above was used, but planting was delayed 3 days.

Visual estimates of vigor of sugar beet seedlings and size of weeds were taken on all plots. While making visual observations of plots receiving the loose-wet treatment, it was noted that beets growing in the outside rows of each 4-row beet drill width were better as to speed of emergence, uniformity of stand, and vigor than those growing in the 2 inside rows. Close inspection revealed that the outside row had been planted in a strip compacted by the rear wheels of the tractor pulling the beet drill. It was further noted that a better stand of beets occurred in the middle rows where the front wheels of the tractor gave similar compaction. The degree of compaction was not measured.

Stand counts on 5 feet of each row were taken on a compacted portion and a non-compacted portion of the loose-wet plots.

The number of foot units having no beets, the emergence rate of seedlings, on 20 feet of each of 8 rows, and the weight, in grams, of 80 sugar beet seedlings per plot were recorded. Every fifth seedling in each of 8 rows was taken until 80 were gathered for weighing.

RESULTS AND DISCUSSION

Experiment 1

Large amounts of green plant material were supplied by the rye, small amounts by field peas, oats, and a mixture of oats and field peas, and intermediate amounts by barley and ryegrass. For example, when harvested in the spring, the total green weight of rye was 22,430 pounds, of barley 11,055 pounds, and of field peas only 146 pounds.

The total emergence of sugar beet seedlings, as shown in table 1, was significantly higher on plots planted to barley than on plots planted to rye or field peas, and significantly higher on plots receiving a wheat straw mulch or planted to ryegrass than on the rye plots. Stand counts for other green manure treatments were approximately equal.

Data presented in table 1 show that the number of marketable beets harvested from the ryegrass and barley plots was significantly greater than from the wheat straw and rye plots. The weight of beets, harvested from plots previously planted to rye and to field peas was significantly less than from plots previously planted to ryegrass, and signifi-

Table 1.—Effect of green manures on stand count of beet seedlings and number and weight of marketable beets—1952.

Green manure treatments	Average per replication		
	Stand count*	Number of marketable beets†	Weight of marketable beets† (pounds)
Wheat straw	176.9	64.1	42.0
Rye	128.3	64.5	44.4
Ryegrass	170.5	78.3	53.9
Barley	190.9	77.0	50.8
Oats	161.1	70.6	49.5
Oats and field peas	158.3	70.1	48.8
Field peas	152.1	72.7	46.3
L. S. D. (5%)	32.99	10.40	6.80

* Average stand count for 40 feet of row.
† Harvest data from 104 feet of row.

cantly less from the wheat straw than from the ryegrass, barley or oat plots. Number and weight differences of beets harvested from other green manure plots were not significant.

In no case was any one tillage treatment significantly better, but the slight differences obtained were always in favor of plowing under the green manure and wheat straw residues.

It appears, from the results of this experiment, that too much green plant material or too little green plant material, from spring growth, resulted in poor seedling emergence and yield of sugar beets. Significant improvement did result where intermediate amounts, as was furnished by barley and ryegrass, were incorporated into the soil prior to planting sugar beets. The low yield of harvested beets on the wheat straw plots may have resulted from the large amount of dry, carbonaceous material supplied by this treatment. The breakdown of this material did not begin in time to interfere with seed germination. In fact, the moisture conditions were more favorable due to the mulch, affording better conditions for germination. The reduction in stand count and number and weight of marketable beets from plots planted to rye was apparently caused by a drier soil at planting time and the slow breakdown of such large amounts of green material.

Experiment 2

The average yield for three cuttings of alfalfa, in pounds of green material per acre, was as follows: June 19—17,480 pounds; Aug. 5—4,577 pounds; Sept. 16—5,815 pounds.

Rye yields on plot portions on which the alfalfa hay was not removed was 2.5 times greater (7,800 pounds green weight per acre) than on plot portions on which the hay was removed (3,073 pounds per acre).

Although green manures ranging in weight of tops per acre from almost 40,000 pounds to practically none were plowed under or worked into the topsoil, none of the treatments appeared to affect the time or vigor of seedling emergence.

As would be expected, plots receiving three cuttings of alfalfa were practically void of alfalfa following tillage treatments. In general, plots which were spring plowed had fewer alfalfa plants remaining than fall plowed plots, but plots which were field cultivated in the fall had fewer remaining than plots field cultivated in the spring. In no case, however, did alfalfa present physical difficulties in the culture of the sugar beets that followed.

The weeds in the plots which were plowed were smaller than on the plots field-cultivated. The weeds on fall plowed plots were smaller than those on spring plowed plots, and smaller where field cultivated in the fall than in the spring. The treatments included in this experiment had no significant effect on number of grass plants and total weeds per plot. However, planting rye following fall field cultivating resulted in significantly fewer broad-leaved weeds than where no cover crop was planted.

Vigor of sugar beet seedlings appeared to be associated with tillage rather than with green manuring treatments. Based on visual vigor readings, using an arbitrary standard, "good" sugar beets were produced on fall plowed plots, and "weak" sugar beets on plots field cultivated in the fall. "Average" beets were produced on all other plots. Growing rye on fall field cultivated plots had no effect on vigor of sugar beets.

No statistical stand count differences were obtained between plots receiving the various treatments. However, the summary of results presented in table 2 shows that a slightly higher total emergence of sugar beet seedlings resulted when all hay was removed than when all or part of the hay was left on the plot. In all cases, seedling emergence appeared to be more closely associated with tillage treatments, the small differences obtained being in favor of spring tillage. Planting rye on fall field cultivated plots resulted in a slight increase in seedling emergence over fall field cultivated plots not planted to rye.

Although treatment differences for the most part were not statistically significant, the amount of green plant material incorporated into the soil in the spring again appeared to be a factor influencing sugar beet seedling emergence. Spring tillage, following removal of two or more cuttings of hay, added an intermediate amount of green plant material to the soil, resulting in higher stand counts. When rye was grown on fall tilled plots, and incorporated into the soil before too much spring growth occurred, increased seedling emergence was obtained.

Experiment 3

Visual estimates of vigor of sugar beet seedlings indicated a higher score for plots receiving the loose-wet treatment and a lower score for plots receiving the loose-dry treatment. Stands always appeared more uniform on the loose-wet seedbed.

Table 2.—Summary of stand counts of sugar beet seedlings before blocking and thinning—1953.

Treatments* (alfalfa)	Average number beet seedlings†
1 cutting, none removed	249.7
2 cuttings, 1st removed	255.8
2 cuttings, all removed	285.1
3 cuttings, all removed	283.5
All fall plowed	251.5
All spring plowed	256.2
All fall field cultivated	255.7
All spring field cultivated	288.5
Fall field cultivated—rye	273.4
Fall field cultivated, no rye	237.9

* Treatment differences were not statistically significant.
† Average stand count for 80 feet of row.

The differences in weed growth on the various plots should be stressed. Plots having a loose-wet soil condition were relatively free of weeds at the time stand counts were taken. This permitted the sugar beet seedlings to get a good start before weed seeds germinated and became a problem. Plots receiving the firm-dry treatment had the most and the largest weeds. The weed seeds germinated before the sugar beet seeds, offering much competition to the beets.

Stand counts given in table 3 show that a significantly higher total seedling emergence was obtained on portions compacted by the tractor wheels than on non-compacted portions of planted rows. Perhaps a lack of uniform rate and depth of planting or a lack of uniform seed distribution resulted from loose-wet tillage practices as applied to seedbed preparation. It may be possible, then, to overcome this lack of uniformity by packing the soil immediately in front of each disk opener, gaining, at the same time, a better seed-soil contact. This packing action was effective, but to a lesser degree, on plots receiving the loose-dry tillage treatment, and least effective on firm-wet and firm-dry plots.

As shown in table 4, significantly fewer units without beet seedlings resulted from the loose-wet and firm-wet treatments than from the loose-dry treatment. The difference between the firm-dry and loose-dry treatments approached significance, with fewer units resulting from the firm-dry treatment. The rate of seedling emergence, indicated by stand counts, was significantly higher on the loose-wet and firm-wet plots than on the loose-dry plots. Stand counts were intermediate on firm-dry plots. No significant weight differences were obtained for any of the tillage treatments.

SUMMARY

The results may be summarized as follows:

1. An intermediate amount of green plant material added to the soil in the spring resulted in a significant improvement of stand count of seedlings and yield of marketable sugar beet roots in comparison with large or small amounts of green plant material.

2. No method of tillage for seedbed preparation was found that gave better stands, vigor or yield of sugar beets than that of plowing in the spring.

3. Emergence of sugar beet seedlings was as high on plots where all the alfalfa hay was removed as on those where all or part of the hay was left the previous year.

4. Sugar beet seedlings emerged earlier from loose-wet and firm-wet seedbeds than from firm-dry and loose-dry seedbeds.

5. Rapid emergence of sugar beet seedlings compared with weed seedlings made weed control easiest on the loose-wet seedbed.

6. At all times throughout the growing season the beets appeared most vigorous on loose-wet plots.

7. A high total emergence of sugar beet seedlings resulted from compacting the row with tractor wheels in the process of planting on the loose-wet seedbeds.

8. A more uniform stand and a higher seedling emergence were obtained when loose-wet and firm-wet seedbeds were used than when the seedbeds were loose-dry or firm-dry.

Table 3.—Total number of sugar beet seedlings on tractor compacted and non-compacted portions of plots receiving loose-wet treatment—1953.*

Planter row	Compacted portion of row	Non-compacted portion of row†
1	42	23
2	37	26
3	32	18
4	31	20

† L.S.D. (5%) between compacted and non-compacted portions = 6.05.
* Stand count for five feet of each row.

Table 4.—The effects of various tillage treatments on sugar beet seedling emergence—1953.*

Tillage treatments	No. of 1-foot units having no seedlings	Stand counts of seedlings	Weight of 80 seedlings
Loose—wet	37.2	1131.2	91.5
Firm—wet	34.0	1169.5	95.4
Firm—dry	63.0	804.0	96.0
Loose—dry	122.5	420.0	71.3
L. S. D. (5%)	66.63	671.46	N.S.

* Data taken on 160 feet of row.

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The Effect of Moisture and Temperature During Storage on Cold Test Reaction of *Zea mays* Seed Stored in Air, Carbon Dioxide, or Nitrogen[1]

S. F. Goodsell, G. Huey, and R. Royce[2]

CONSIDERABLE interest has developed in the "cold test" reaction or germination test as a criterion of the influence of various heritable and environmental factors on the ability of *Zea mays* seed to germinate after exposure for a brief period of time to conditions unfavorable to germination. Seeds are generally exposed to soil borne pathogens under conditions favorable to the pathogens and not favorable for germination of the seed. Later, when conditions more favorable for germination are restored, seeds whose embryos have not been invaded and injured by pathogens may germinate and produce normal seedlings. The tests in general usage are assumed to simulate cold, wet weather or, in some instances, flooding conditions taking place in the field after the seed is planted.

Standard or normal germination or field tests under generally favorable conditions have been used to evaluate the effects of different storage factors on germination of corn seed. These tests are probably adequate for the conditions defined. However, under certain conditions, the cold test may provide means for making a more critical evaluation of some of the factors which contribute to longevity of the seed.

REVIEW OF LITERATURE

There is evidence[3] that old seed or seed improperly stored for a period of time, even though its total viability under favorable conditions may be high, will produce poor field stands under conditions which favor soil borne pathogens but inhibit germination of the seed. Rush and Neal (8) indicate that age of seed influenced cold test germination. Livingston (5) and Rush and Neal (8) have presented evidence that early harvested seed which is artificially dried was lower in cold test germination than seed harvested later at a more mature stage.

Welton (11) reported that seed germinated well for 4 years and then began to decline in germination up to 12 years after which there was no further germination. A loss in vigor in the seedlings accompanied the decline in germination. Robertson, *et al.* (6) reported that seed of about 10% moisture stored in a dry unheated room germinated 32% after 21 years and that there had been a gradual decline in viability from the beginning of the experiment. A dry climate was considered as contributing much to the longevity of farm seeds. Dungan and Koehler (1) reported seed at about 10.5% moisture and initially infected with ear rot pathogens germinated 11 to 32% after 10 years storage in a tin box. Haferkamp (2) *et al,* reported six varieties of corn seed stored in miscellaneous containers at Pullman, Wash., where mean annual rainfall is only 11.4 inches, germinated from 0 to 70% strong seedlings after 32 years of storage.

Sayre (9) tested seed after storage by planting in the field at normal corn planting time. In one experiment, seed was stored at "room temperature". Seed at 18% moisture was dead in 1 year or less, seed at 14% moisture had decreased in germination in 3 or 4 years, seed at 7.5 and 11% moisture germinated satisfactorily after 7 years while seed at 5% moisture germinated 80% after 13 years of storage. In another experiment, seed at 7.5 and 11.0% moisture held at 72.0° F. and 28° F., germinated 80% or better after 6 years storage. Seed at 14.6% moisture and stored at 28° F. germinated 80% while seed at 18.2% moisture stored at 28° F. was only 13% viable after 6 years. In a third experiment seed at 11.2% moisture was sealed in air, carbon dioxide and oxygen and stored at 86°, 37° and 0° F. and tested for 13 years. Storage in carbon dioxide was found to be no better than storage in air and storage in oxygen was found to be somewhat poorer than either air or carbon dioxide. The effect of temperature was far greater than that of gases. Seed stored in air, carbon dioxide or nitrogen and held at 0° and 37° F. was still 96 to 98% viable after 13 years, while seed stored at 86° F. was decidedly lower in viability after 3 years and completely dead after 8 years.

Dungan and Koehler (1) found that carefully hand harvested seed of Station Yellow Dent corn yielded progressively less as the age of the seed increased and the yield was significantly less for seed 4 to 10 years old. The yield reductions were related to reduction in field stands. There was very little difference between 1- and 2-year old seed but 3- and 4-year old seed yielded 3.5% and 5.6% respectively, less than 1-year old seed. In a test of commercially produced hybrid corn seed, 2-year old and 3-year old seed was found to yield 5.5% and 8.7% respectively, less than 1-year old seed. Yellow Dent seed up to 7 years old yielded progressively less than 1-year old seed under perfect stand conditions. Old seed produced plants lacking the vigor of new seed. Seed 3 years old yielded 4.8% less than 1-year old seed with perfect stands and 7.8% less with no adjustment in stand.

The present report is a condensation of data obtained over a period of 5 years in a cooperative experiment. Data on the effects of temperature and moisture on cold test germination of seed stored in carbon dioxide, air, or nitrogen gas, are summarized and discussed.

The original experiment included samples of three hybrids at seven moisture levels treated with three different fungicides. A series of non-fungicide treated samples was also included. Only data for one fungicide treatment of four different moisture levels for two hybrids are presented in this paper. These selected data are considered representative of those obtained in the entire experiment which comprised a total of 84 lots made up of different combinations of varieties, moisture contents and seed treatments. (With the various closure and storage conditions used, a total of 720 variables made up of approximately 7,000 individual samples were included in the over-all program.)

MATERIALS AND METHODS

In order to obtain the representative data discussed herein, commercially produced seed of two hybrids grown in 1947 was procured. The seed of one hybrid had been classified as "strong" and the other "weak" on the basis of cold test reaction of non-treated seed and was 9 months old before the storage experiment was started in 1948.

The seed of each hybrid was divided into lots and each lot adjusted to a different nominal moisture level by further drying or by adding water in small increments and equilibrating at a low temperature.

Each lot of seed was treated with the fungicide, Arasan S. F., at the rate of 0.3 ounces of Thiram per bushel and divided into four sets of multiple 2-pound samples. Each sample was placed in a sanitary style tin can and the can hermetically sealed.

Within each of the four sets of samples, air in a proportionate number of the cans was replaced with either carbon dioxide or nitrogen gas.

Each set of samples was placed in a different storage room where the temperature was controlled at either 0°, 40°, 60°, or 85° F.

A sufficient number of samples was placed in each storage room so that tests could be made each 6 months for 5 years.

[1] Contribution from Germination Department, Pioneer Hi-Bred Corn Co. Laboratory, Johnston, Iowa; and Central Division Laboratory, American Can Co. Maywood, Ill. Rec. for publication Aug. 20, 1954.

[2] In charge of Germination Department, and Assistant Plant Manager, respectively, Pioneer Hi-Bred Corn Co.; and Assistant Manager, Central Division Laboratory, American Can Co.

[3] Unpublished data from Pioneer Hi-Bred Corn Co.

At each 6-month interval, samples were removed from storage and tested for moisture, normal germination and cold test germination.

Moisture determinations were made with a Steinlite moisture meter. Although the moisture content of a given sample in these sealed cans could not change with storage time, the values used in this report are taken as the averages for the moisture level at the beginning of the experiment and after 5 years of storage. The mean moisture percentages averaged 0.2% less than the nominal values of 8, 10, 12 and 14%. The nominal percentages are used in the discussion of the data presented in this report.

Table 1.—Mean cold test germination percentages* for two classes of seed stored zero to five years in three gases at three storage temperatures.

Class	Gas	Years in storage at 0° F.				
		0	1	2	3	5
Weaker	Carbon dioxide	73	63	74	74	62
Weaker	Air	73	64	72	74	59
Weaker	Nitrogen	73	65	76	73	68
Stronger	Carbon dioxide	85	80	89	86	80
Stronger	Air	85	81	87	87	80
Stronger	Nitrogen	85	80	89	87	79
		Years in storage at 40° F.				
		0	1	2	3	5
Weaker	Carbon dioxide	73	63	71	71	61
Weaker	Air	73	65	73	71	59
Weaker	Nitrogen	73	65	74	68	61
Stronger	Carbon dioxide	85	78	86	84	79
Stronger	Air	85	80	87	89	73
Stronger	Nitrogen	85	79	87	87	82
		Years in storage at 60° F.				
		0	1	2	3	5
Weaker	Carbon dioxide	73	61	66	61	32
Weaker	Air	73	64	66	44†	23†
Weaker	Nitrogen	73	55	66	59†	42†
Stronger	Carbon dioxide	85	78	81	79	63
Stronger	Air	85	80	84	80	58
Stronger	Nitrogen	85	75	79	82	56

† Slightly less than 90% normal germination.

* Percentages within each column were obtained in the same test are directly comparable. Percentages for different columns or years are reports of 5 separate tests and varying germination levels are in part due to differences in pathogenicity of soil borne organisms from one test to another.

Normal or standard germination was determined by the use of "paper dolls". Each sample was represented by five 100-seed replicates in the test. The percent of strong seedlings was determined after incubation for five days at 80° F.

The following procedure was used to determine cold test reaction: *(1)* Seeds were placed embryo down on a ¼-inch layer of subirrigated non-sterilized corn field soil in seed trays. *(2)* Prepared trays were placed in a cold room and held at 50° F. for 7 days. *(3)* After "cool weather" treatment, trays were removed to a germination room and held for 4 days at 80° F. after which seedling counts were made. Ten 100-seed replicates were planted for each sample cold tested.

The soil for the cold test determination came from the same general field area during the 5 years of testing. As nearly as possible, temperature and time controls were maintained at the same level for each test.

Percentages were transformed to angles for the analysis of variance. Data for seven test periods after storage at 0°, 40° and 60° F. were included in the analysis of variance. Samples tested after 3½ and 4 years included air storage only, and no samples were tested at 4½ years of storage.

RESULTS AND DISCUSSION

Mean normal and cold test germination percentages after storage for 1, 3 and 5 years at different storage temperatures and moisture levels are illustrated by the diagrams in figure 1. Each percentage illustrated was calculated from the pooled data for the two hybrids and three storage gases.

Mean cold test percentages in table 1 are for samples stored 0 to 5 years at different temperatures after sealing in atmospheres of carbon dioxide, air and nitrogen. Percentages for samples stored at approximately 8, 10 and 12% were averaged for each seed class. Except where noted in table 1, normal germination was 95% or better at each test period for each sample tested.

Normal germination or total viability is indicated in the diagrams of figure 1 by the open bars. Generally, germination was still 95% or better after 5 years for samples of seed at 8, 10 and 12% moisture stored at 0° and 40° F. and seed at 8 and 10% moisture stored at 60° F. Seed at 12 or 14% moisture stored at 60° and 8 and 10% moisture stored at 85° deteriorated rapidly after 1 year of storage. Seed at 12 or 14% moisture was practically all dead after ½ to 1 year of storage at 85° F.

The data indicate that cold test germination of samples of seed at 8 and 10% moisture stored at 0° to 40° F. was about as high after 5 years of storage as at the beginning of the experiment. Seed at 12% moisture was only slightly lower in germination after storage at 0° F. and significantly lower after storage at 40° F. for 5 years. Seed at 14% mois-

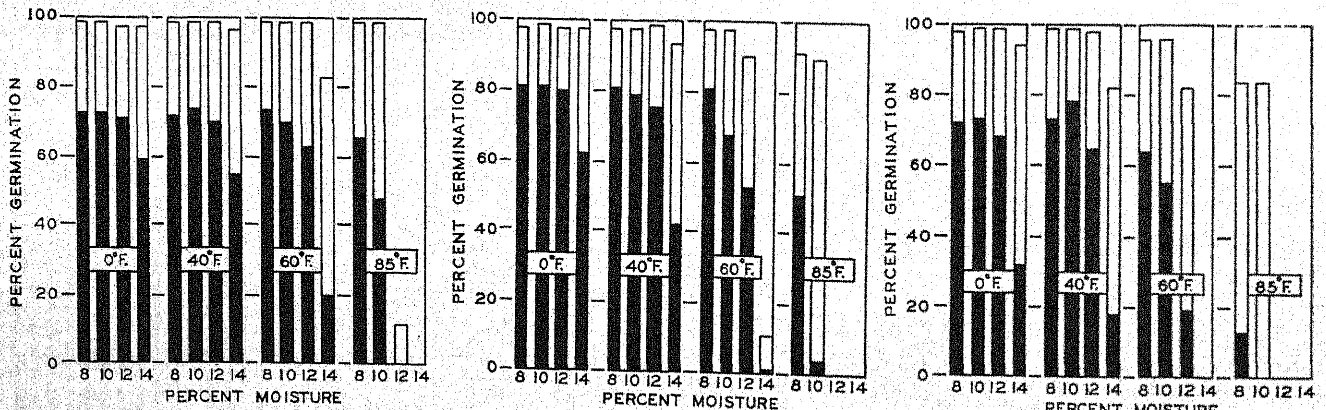

FIG. 1.—Cold test and normal germination percentages represented by solid bar and open bar respectively, after storage of seed at four moisture levels at four different temperatures. Left—After storage for one year. Middle—After storage for three years. Right—After storage for five years.

ture was significantly lower in germination after ½ year of storage at either 0° or 40° F.

Seed stored at 60° F. was significantly lower in cold test germination after ½ to 1 year of storage of samples held at 12 or 14% moisture. Seed at 8% moisture maintained its original germination for 3 years and seed at 10% moisture for 2 years of storage.

Seed at all four moisture levels was significantly reduced in cold test germination after storage at 85° F. for ½ year.

The data from the analysis of variance indicate that a greater part of the variance was contributed by seed classes. Interactions involving seed classes were relatively small. Significant interaction values are due to the greater deterioration in storage of the weaker hybrid at higher moisture levels and higher storage temperatures.

Variances due to storage temperatures and moisture levels and interactions involving these variables are relatively high because seed at 12% moisture stored at 60° F. deteriorated more rapidly than seed at lower moisture levels stored at lower temperatures.

The significant values for the test periods in the analysis of variance are partially due to differences in pathogenicity of the seed rot organisms from one test period to another. An example of this variation is shown in the data in table 1 for percentages on samples stored at 0° and 40° F. Germination percentages obtained after 1 or 5 years of storage are considerably lower than those obtained at the beginning or after 2 or 3 years of storage. However, within any one test period, all samples were included in the same germination trial and may be considered as directly comparable.

Cold test germination of samples stored in carbon dioxide or nitrogen was generally no better than germination of samples stored in air. Variances contributed by storage gases or interaction involving storage gases were generally insignificant except that a small significant value was calculated for test periods × gases. Seed of the weaker hybrid at 12% moisture stored at 60° F. in air germinated relatively lower during later test periods than comparable samples stored in carbon dioxide or nitrogen.

A number of miscellaneous remnant samples of untreated seed included in the experiment were treated with Arasan SFX and Orthocide 75 applied at 0.75 ounces of active ingredient per bushel after 5 years storage and tested. These samples were all 95% or better normal germination and represent different combinations of storage conditions. Cold test germination percentages for these samples and comparable samples which had been treated in 1948 and also tested after 5 years storage were very similar. Fungicide treatment at either the lighter or heavier dosage rate failed to protect the seed of each sample against soil borne pathogens equally as well after 5 years of storage as the lighter application protected all samples at the initial test period. The failure of fungicide to give full protection to all samples of old seed, although of 95% or more normal germination, has been observed in other experiments.

The exact reasons for increase in susceptibility to soil borne pathogens with increase in age of seed is not well understood. Studies by Hottes and Huelson (4) indicated that germination and vigor were related to permeability of the seed. The increase in permeability was suggested to accompany changes in the physiological condition of the protoplast and the physiological changes may be the result of environmental factors such as exposure to heat or chemicals. Studies by Robinson (7) indicated a relationship between permeability and germinating power. Tatum (10) found a correlation between diffusion products in steep water and cold test reaction. Low cold test reaction was associated with low light transmission readings made spectrophotometrically. Degree of turbidity was considered to be directly related to permeability.

Hassan Ragai and Loomis (3) reported studies on the relationship of moisture in the grain and temperature to respiration rates in maize. Immature grain picked with a high moisture content gave the same moisture relations as mature seed with 8% moisture which had been moistened to levels varying from 14 to 24% moisture but the rates for immature grain picked at a high moisture level were only one-sixth as high at the same moisture levels. Respiration rates increased with increase in temperature and were not affected by the presence of a Ceresan-M treatment.

The experiments reported by Hottes and Huelson (4) and Tatum (10) indicate that leached products may support fungus growth.

The relatively greater susceptibility of seed samples stored at higher moisture levels and at higher temperatures to soil borne pathogens is probably due to the presence of larger quantities of diffusion products from the more permeable seed. Apparently these diffusion products occur in sufficient quantity to support fungus growth even in the presence of fairly heavy fungicide treatment.

SUMMARY AND CONCLUSIONS

Seed samples at approximately 8, 10, 12 and 14% moisture were sealed in cans with atmospheres of carbon dioxide, air or nitrogen and stored at 0°, 40°, 60° and 85° F. At 6-month intervals for 5 years, normal and cold test germination percentages and moisture percentages were determined for a set of samples which had been stored under the various conditions.

Fungicide treatment was not as effective against soil borne pathogens under cold test conditions on samples stored at higher moisture levels and temperatures as on samples stored at lower moisture levels and temperatures.

Fungicide treated seed held at 8, 10, or 12% moisture and stored at 0° F. or at 8 or 10% moisture and stored at 40° F. germinated as well in a cold test after 5 years storage as at the beginning of the experiment. Seed held at 12% moisture and stored at 40° F. and at 8% moisture and stored at 60° F. maintained its original cold test germination for 3 years. Seed held at 10% moisture and stored at 60° F. was only slightly reduced in cold test germination after 1 year of storage. Under all other conditions, cold test germination was significantly lower after ½ to 1 year of storage than at the beginning of the experiment.

Cold test germination percentages were, in general, no higher for seed stored in atmospheres of carbon dioxide or nitrogen than for seed stored in air, except that seed of the weak hybrid at 12% moisture stored in air at 60° F. germinated relatively lower during later test periods than comparable seed stored in carbon dioxide or nitrogen.

At higher moisture levels and storage temperatures, seed of the weak hybrid was slightly more susceptible to cold test pathogens than seed of the strong hybrid. There was no difference in relative susceptibility from one test period to another, between the hybrids for seed stored at 10% moisture or less.

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Laboratory Evaluation of Fungicides for the Preservation of Moist Hay[1]

R. U. Schenk and W. K. Kennedy[2]

MOLD growth on moist hay in equilibrium with air of 85% relative humidity was prevented in the laboratory by Dawson, *et al.* with 2,4,5-trichlorophenyl acetate, 2,4,6-trichlorophenol, and 2,4,5-trichlorophenol applied at the rate of 0.30% of the hay weight (2). However, Kennedy and Schenk could not control effectively mold growth in baled alfalfa hay containing 30% moisture if 2,4,6-trichlorophenol was applied at rates lower than 0.50% (3). Even at the rate of 0.50%, occasional mold spots were present in the baled hay and the loss of dry matter during storage was higher than Dawson, *et al.* observed in their laboratory tests. Kennedy and Schenk also found that during the storage period, moist hay treated with a fungicide that prevented mold growth remained somewhat higher in moisture content than untreated hay. Because of this moisture retention, treated hay will mold if the chemical becomes ineffective during storage unless the chemical sterilizes the hay. Kennedy and Schenk emphasized that for field treatment, it probably would be necessary to use a chemical at two or three times the effective laboratory rate, since uniform application of a small amount of chemical to a bulky material such as hay is very difficult if not impossible (3).

Considering the rate of application necessary for treating baled or loose hay that is too moist for safe storage and the residue problem in milk of dairy cows receiving treated hay, 2,4,6-trichlorophenol was not recommended as a hay preservative by Kennedy and Schenk (3). They concluded that it would be practical to preserve moist hay by treating with a highly effective fungistat or fungicide only if the chemical was inexpensive, was not harmful to either humans handling the chemical or animals consuming the hay, and if it left no undesirable residues in the animal produce (3).

[1] Contribution from the Agronomy Department, Cornell University Agr. Exp. Sta., Ithaca, N. Y. Acknowledgement is made to The Dow Chemical Co. for partially financing the project. Rec. for publication Aug. 23, 1954.

[2] Research Assistant and Professor of Agronomy, Cornell University, respectively.

Kennedy and Schenk also concluded that a chemical was worthy of extensive field testing only if it prevented growth of molds in moist ground hay for a prolonged period of time in the laboratory at economical rates of application. Chemicals that delayed mold development in moist ground hay for several weeks in the laboratory frequently were unsatisfactory when applied at the time of raking or baling to alfalfa hay containing 30% moisture. For example, o-dichlorobenzene successfully preserved moist hay under laboratory conditions for a period of 6 to 8 weeks but eventually allowed mold growth to occur. In the field, mold growth was delayed very little in moist baled hay treated at the time of raking with o-dichlorobenzene; and by the end of a 6 months storage period the treated hay was just as moldy and had lost just as much dry matter as untreated moist hay (3).

Since trichlorophenol had definite limitations which prevented it from being recommended as a hay preservative, the search for a compound superior to trichlorophenol was continued. The laboratory procedure used by Musgrave and Dawson was very accurate but required more equipment and detail than was practical for large-scale screening of many compounds (1, 2, 4).

The purpose of this study was to find a simple laboratory method of determining the effectiveness of a chemical to control mold growth in moist hay, and then to compare a large number of compounds which might be used as preservatives for moist hay with 2,4,6-trichlorophenol.

PROCEDURE

The work reported in this paper was initiated in the fall of 1949 and was completed in the spring of 1954. It consisted of seven separate experiments as well as a number of preliminary experiments. The method for determining the effectiveness of different chemicals to prevent mold growth in moist hay was modified from time to time as new information was obtained and procedures were improved. Basically, however, the method remained much the same for all experiments.

Samples of alfalfa hay that had been passed through a hammer mill with a screen having holes 1/8-inch in diameter were rehydrated to 25, 30 or 40% moisture, and treated with chemicals at rates economically practical and stored at room temperature for 4 to 11 weeks. The coarsely ground alfalfa hay was rehydrated by adding a calculated amount of water. Because hay rehydrated to 25 or 30% moisture tended to become dry within a few weeks, the initial moisture level was raised to 40% in most of the tests reported in this paper. At this level the hay remained moist for a longer period. In the calculation, the initial moisture content of the hay was assumed to be 12% since most stored hay was found to have about this moisture content. No attempt was made to measure or control the moisture potential because the moisture content of the hay was sufficiently high for rapid mold growth (1).

The rehydrated hay was weighed into 60.0- to 75.0-gram samples. Each sample was thoroughly mixed with a chemical in a 1000-ml. beaker. In the early part of this study, all chemicals were applied at the rate of 0.50% by weight, but this procedure was soon modified because some chemicals were far too expensive to be used at this concentration, while others were cheap enough to be used at higher rates. For most of the study, each chemical was added at two or more rates. The highest rate was at least twice as great as was considered economical. The chemicals were tested at this upper rate to make certain any compound which was reasonably effective would not be eliminated before it had been thoroughly evaluated. Each treated sample was stored in a cotton stoppered 250-ml. Erlenmeyer flask at room temperature for 4 to 11 weeks. At least three samples were treated with each chemical.

The chemicals usually were applied as ethanol solutions. For those compounds insoluble in ethanol, either a different solvent was used or the chemical was applied directly to the hay. Check samples of hay were treated with these different solvents. When the chemical was applied directly to the hay, ethanol was added to make all treatments comparable. Half of the check treatments were treated with ethanol and half were left untreated.

Approximately every sixth sample of rehydrated hay was placed in a small paper bag, dried at 70° C. for 24 hours, and reweighed to determine the actual moisture content of the hay at the time treatments were applied. From these moisture measurements, the amount of dry matter stored in each flask was determined.

In the first few tests the hay was rehydrated to a moisture content of 25 or 30% and the samples were removed from the flasks after a 4-week incubation period, oven dried and weighed. From these measurements the dry matter losses that occurred during storage were calculated. While the precision of this method of testing was good, the storage period was not long enough to separate the effective chemicals from the partially effective ones. The latter merely delayed mold growth for 3 or 4 weeks but molding occurred when the hay remained moist for a longer period. To improve the testing method, the initial moisture content was increased to 40% and the storage period was extended to 11 weeks. Even with an initial content of 40% moisture the samples dried within 11 weeks to such a low moisture level that molds could not grow on either the treated or untreated hay.

In the last experiment (spring of 1954) only the samples of the effective treatments were remoistened at the end of the 11-week storage period to a moisture content of about 42% by adding water which contained a heavy concentration of mold spores. These samples were stored for 8 additional weeks to determine if molding would occur.

In one test which included 84 individual flasks, the contents of each flask were examined at semi-weekly intervals for the first 2 weeks and at weekly intervals for the remaining 9 weeks of the storage period for signs of first visible mold growth. At the end of 11 weeks, the hay in each flask was rated as to total visible mold growth. A rating scale of 1 to 10 was used. Hay with no visible mold growth received a rating of 1, while hay with a mass of mold mycelia such as untreated hay received a rating of 10. After the hay was rated, the contents of each flask were oven dried and weighed to determine dry matter loss. The correlation and regression coefficients for percent dry matter loss and the mold rating were computed.

RESULTS

Incubating treated and untreated rehydrated ground alfalfa in Erlenmeyer flasks at room temperature for a period of 4 weeks was found to be a simple method of determining whether or not a chemical had fungicidal or fungistatic properties. By measuring the percentage of original dry matter of treated and untreated samples remaining after a 4-week incubation period, the effectiveness of each chemical was determined (table 1). The standard error for the individual determination was 0.6% dry matter loss. In this trial all chemicals except sodium o-phenylphenate were effective in preventing mold growth and losses of dry matter in hay containing 25 or 30% moisture. The rate of application was 0.50% as a solid or as a solution. When treated with sodium o-phenylphenate, only a very slight amount of visible mold occurred in the hay containing 25% moisture. In hay containing 30% moisture, mold growth was general but not profuse, while in the check treatments mold growth was heavy for both moisture levels but more severe in the wetter hay.

In a subsequent experiment, several compounds were tested by treating hay containing 30% moisture and then storing for 4 weeks and observing resultant mold growth (tables 2 and 3). The chlorinated phenols, o-phenylphenol, 2,4,5-trichlorophenyl chloroacetate, and dehydroacetic acid were very effective in controlling mold growth. The dichlorobenzenes were less effective; when applied at the rate of 0.50%, mold growth was delayed but not completely inhibited; but when applied at the rate of 1.00%, mold growth was prevented for the 4-week incubation period.

Several of the chemicals listed in table 3 delayed or decreased the amount of molding that occurred, but none of them prevented mold growth for the 4-week storage period.

Table 1.—Percent dry matter recovered from alfalfa hay rehydrated to 25 and 30% moisture and incubated for 4 weeks after being treated with fungicides in solution and as a dust at the rate of 0.50%.

Chemical	Dry matter recovered			
	25% moisture		30% moisture	
	Solution	Dust	Solution	Dust
	%	%	%	%
2,4,6-Trichlorophenol	100.0	100.4	99.8	100.2
2,4,5-Trichlorophenol	100.1	100.2	100.1	100.5
Sodium 0-phenylphenate	96.4	98.6	90.7	92.7
Sodium 2,4,5-trichlorophenate	100.1	100.3	100.1	100.3
0-Phenylphenol	100.1	100.4	100.2	100.5
Check	83.4		74.1	
LSD 1%				
Chemical 0.6				
Method of application N.S.				

Table 2.—Chemicals which prevented mold growth for 4 weeks in hay containing 30% moisture.

Chemical	Rate applied
	%
2,4,5-Trichlorophenol	0.25
2,4,6-Trichlorophenol	0.25
0-Phenylphenol	0.40
2,3,4,6-Tetrachlorophenol	0.50
2,3,6-Trichlorophenol	0.50
2,4,5-Trichlorophenyl chloroacetate	0.50
p-Dichlorobenzene	1.00
o-Dichlorobenzene (Technical grade)	1.00
Dehydroacetic acid	0.50

Table 3.—Chemicals which did not prevent mold growth for 4 weeks in hay containing 30% moisture.

Chemical	Rate applied
	%
Sulfur dioxide	1.00
Calcium hypochlorite	0.50
Paraformaldehyde	0.50
Bromine	0.50
4- and 6-Chloro-2-phenylphenol	0.50
2-Chloro-4-phenylphenol	0.50
p,p'-Isopropylidenediphenol	0.50
2,2-Methylenebis (4-chlorophenol)	0.50
3-Phenylsalicylic acid	0.50
Bis(p-chlorophenoxy) methane	0.50
p-Chlorophenyl p-chlorobenzenesulfonate	0.50
Sodium trichloroacetate	0.50
Phenothiazine	0.50
2-Cyclohexyl-4,6-dinitrophenol	0.50
Disodium ethylenebisdithiocarbamate	0.20
Ferric dimethyldithiocarbamate	0.10
2-(p-Chlorophenoxy) ethanol	0.38
p-Chlorophenoxyacetic acid	0.50
2,4'-Dihydroxybenzophenone	0.50
Pentachlorophenoxyacetic acid	0.50
p-Hydroxyacetophenone	0.50
Bis(p-Chlorophenyl) carbonate	0.50
3,5-Dichlorosaligenin	0.50
Salicylamide	0.50
(alpha-Methylbenzyl)phenol mixture	0.50

Since the compounds listed in table 3 delayed mold growth for varying periods of time and modified total mold growth to different degrees, it was considered worthwhile in subsequent experiments to obtain some index of the relative effectiveness of the compounds tested. The testing procedure was made more rigorous by increasing the initial moisture content for the ground hay from 30 to about 40% and by extending the incubation period to 11 weeks. The time of first visible mold growth was recorded, and at the end of the incubation period the samples were rated from 1 (no mold growth) to 10 (heavy mold growth). Then the dry matter loss of each sample was determined.

The agreement between mold rating and the dry matter loss was very good. The correlation coefficient was 0.94, and the regression equation was $y = -1.54 + 2.00x$ where y equals the percent of dry matter lost and x equals the rating for mold growth (figure 1). The regression coefficient, $b = 2.00$, was significant at the 1% level and the standard deviation from regression was 2.01% dry matter loss.

The time of first visible molding was negatively correlated with the rating for mold growth and dry matter losses. However, time of first mold growth was not as accurate an index for estimating dry matter losses as was the rating for moldiness. Certain chemicals would prevent visual mold development for several weeks; but when molding started, it developed very rapidly and by the end of the incubation period the total mold growth was nearly as great as in untreated samples. Other chemicals did not delay mold development for more than a few days but did control the amount of mold growth throughout the storage period.

The chemicals which did not prevent mold growth in hay containing 40% moisture for the 11-week storage period are listed in table 4. While most of these chemicals had certain fungicidal or fungistatic properties, many of them merely delayed and decreased the intensity of mold growth on the moist hay. Dehydroacetic acid, benzyl chloride and the dichlorobenzenes, had been effective in previous laboratory experiments where the initial moisture content of the hay was 30% or the length of storage was less than 11 weeks.

Those chemicals which prevented the appearance of visible mold growth for the entire 11-week storage period are listed in table 5. The halogenated phenols were effective in controlling mold growth at the rate of 0.30% or less, with the possible exception of pentachlorophenol which was not effective at 0.25% but was effective at 0.50%. The actual differences in ability to control mold growth between the other halogenated phenols appeared to be very small.

Chlorination did not appreciably improve the fungus inhibiting properties of salicylaldehyde. The 5-chlorosalicylaldehyde was effective at a lower rate in this test but it did not show any greater effectiveness in an earlier trial on moist oats. The oximes of these compounds were considerably less effective in these studies than were their parent compounds.

A number of halogenated aliphatic aldehydes and ketones were effective mold inhibitors. The ketones controlled molding at very low rates and appeared to be more effective than the aldehydes. The effectiveness of these compounds appeared

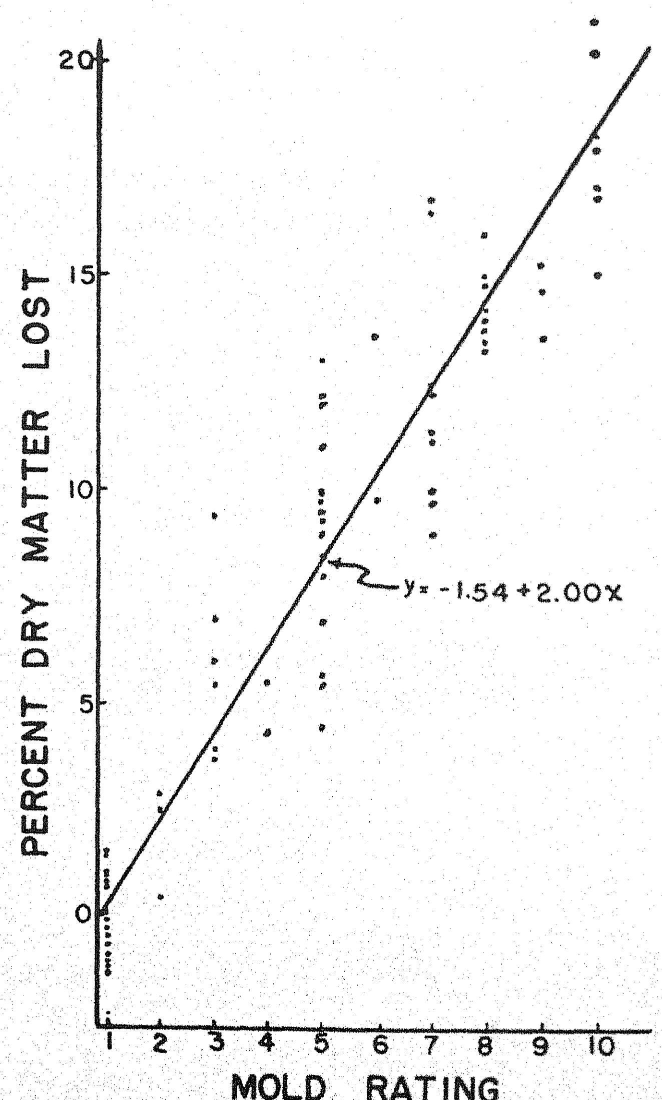

FIG. 1.—Relationship of degree of moldiness and percent dry matter lost in hay containing 40% moisture and stored for 11 weeks. (Mold rating scale: 1, no mold growth; 10, very heavy mold growth).

Table 4.—Chemicals which did not prevent mold growth for 11 weeks in hay containing 40% moisture.

Chemical	Maximum rate tested	Mold rating*
	%	
Check	—	10
Ethanol	5.00	8
Ethylene dibromide	0.50	4
Ethylene dichloride	0.50	4
Trichloroethylene	0.50	6
Tetrachloroethylene	0.50	6
Methylene chloride	6.00	6
Dibromodichloromethane	0.50	4
1,3,3-Trichloropropene	0.50	6
Hexachloropropene	0.50	2
2-Bromo-2-methyl-propane	0.50	6
Benzene	0.50	8
Chlorobenzene	0.50	8
o-Dichlorobenzene (technical grade)	1.00	2
p-Dichlorobenzene	0.60	3
Trichlorobenzene (1,2,4- and 1,2,3-)	0.60	2
1,2,4,5-Tetrachlorobenzene	0.50	8
Hexachlorobenzene	0.50	8
Bromobenzene	0.50	6
1,2-Dichloro-x-ethylbenzene	0.50	6
Benzyl chloride	1.10	3
Acetophenone	0.30	4
Acetophenone oxime	0.30	4
p-Chloroacetophenone	0.30	3
p-Chloroacetophenone oxime	0.30	4
3,5-Dichlorosalicylaldehyde oxime	0.30	7
Salicylic acid	0.50	8
Phenyl salicylate	0.50	8
2,4-Dichlorophenoxyacetic acid	0.50	8
2,4,5-Trichlorophenoxyacetic acid	0.50	8
Sodium o-phenylphenate	0.50	4
Sodium pentachlorophenate	0.50	5
Dehydroacetic acid, sodium salt	0.75	4
Dehydroacetic acid	0.75	7
Chloroacetic acid	0.50	6
Dichloroacetic acid	0.50	4
2,4-Hexadienoic acid	1.20	7
Methyl chloroacetate	0.50	8
Allyl trichloroacetate	0.50	4
Allyl bromoacetate	0.50	2
Diethyl bromomalonate	0.50	7
Bis(2-chloroethyl) ether	0.50	4
Clycine copper chelate	0.50	10
Chloroacetaldehyde diethyl acetal	0.50	4
2,4,6-Trichloroparaldehyde	1.20	7
Dipropylene glycol	6 ml./100 gm. of hay	2
3-Hydroxy-2-methyl-1,4-pyrone	1.20	7
Lime-sulfur	11 ml. of concentrate /100 gm.	9
Sulfur	4.00	9
Sodium sulfite	4.00	9

* Mold rating system: 1, no molding; 10, extremely moldy.

Table 5.—Chemicals which prevented mold growth for 11 weeks in hay containing 40% moisture.

Chemical	Minimum effective rate	Effective rate after rehydration
	%	%
p-Chlorophenol	0.20	0.30
2,4,6-Trichlorophenol (Trichlorophenol)	0.25	0.30
2,3,4,6-Tetrachlorophenol	0.20	>0.30*
Pentachlorophenol	0.50	—†
2-Bromo-4-chlorophenol	0.20	>0.30*
2-Bromo-4,6-dichlorophenol	0.20	>0.30*
p-Bromophenol	0.20	>0.30*
2,4,6-Tribromophenol	0.30	>0.30*
2,4,5-Trichlorophenyl chloroacetate	0.50	>0.50*
Salicylaldehyde	0.20	0.20
Salicylaldehyde oxime	0.20	—†
5-Chlorosalicylaldehyde	0.10	0.20
5-Chlorosalicylaldehyde oxime	0.30	>0.30*
3,5-Dichlorosalicylaldehyde	0.20	>0.30*
Salicylaldehyde copper chelate	0.20	—†
2,3-Dichloropropionaldehyde	0.50	—†
(Chloroacetyl) urea	0.30	—†
Chloroacetaldehyde (B.P. 85° C)	0.30	—†
1-Chloro-2-propanone (B.P. 117° C)	0.10	>0.16*
3-Chloro-2-butanone (B.P. 115° C)	0.16	>0.16*
1-Chloro-2-butanone (B.P. 135°C)	0.10	0.16
1- and 3-Bromo-2-butanone (B.P. 133° and 145° C)	0.07‡	>0.16*
alpha-Chlorocrotonaldehyde (B.P. 148° C)	0.07‡	>0.16*
1- and 3-Chloro-4-methyl-2-pentanone (B.P. about 170° C)	0.07‡	>0.16*
Dowanol 93B-2 (mixed methyl esters of propylene and polypropylene glycols)§	2.00	—†
1-Methoxy-2-propanol	3 ml./100 gm. hay	6 ml./100 gm. hay
Dipropylene glycol methyl ether (B)	3 ml./100 gm. hay	3 ml./100 gm. hay
Tripropylene glycol methyl ether (B)	6 ml./100 gm. hay	6 ml./100 gm. hay
Sodium metabisulfite	2.50	—†
Divinylbenzene-ethylvinylbenzene mixture	0.30	>0.30*
alpha-Bromotoluene	0.20	>0.30*
Methyl 2,3-dibromopropionate	0.10‡	>0.30*

* Maximum rate in this test.
† Not included in this test.
‡ Minimum rate tested.
§ Dowanol is a registered trade mark of The Dow Chemical Co.

to be inversely related to their volatility. All of these compounds were effective at their minimum rate of application for the first 8 weeks of storage. After this time mold growth appeared on the hay receiving the minimum rates of the compounds which have the lowest boiling points.

At the end of 11 weeks the samples of the effective treatments were rehydrated to 42% moisture and inoculated with mold spores. The rehydrated samples were stored for an additional 8 weeks. The hay treated with p-chlorophenol, 2,4,6-trichlorophenol, salicylaldehyde, 5-chlorosalicylaldehyde, 5-chlorosalicylaldehyde oxime, 1-chloro-2-butanone and the methyl esters of propylene and polypropylene glycols remained free of mold growth throughout the extra storage period (table 5). This indicated that these fungicides were still present and effective at the end of 19 weeks. The other chemicals including all but one of the halogenated aldehydes and ketones were ineffective for the second storage period at the maximum rate tested. The values for 1-chloro-2-butanone are questioned because it has a relatively low boiling point.

DISCUSSION

From the results of these laboratory studies and the field work previously published (3), it appeared that a chemical must pass very stringent laboratory testing before it is worthy of field testing as a wet hay preservative. Any chemical that allowed the slightest amount of visible mold growth to develop on moist hay in the laboratory, where the compound could be uniformly applied, did not control mold growth on wet hay treated in the field where uniform distribution is almost impossible.

When ground alfalfa hay containing 40% moisture was treated with a chemical and stored in a cotton stoppered 250-ml. Erlenmeyer flask, it was possible at the end of 11 weeks to determine the relative effectiveness of each chemical for preventing spoilage of moist hay by visually estimating the degree of moldiness. With this laboratory method the fungicidal properties of many chemicals could be ascertained in terms of their probable preservative values when applied to large quantities of moist hay stored in stack or mow. The limitation to the procedure was that the hay rehydrated to a moisture content of 40% gradually dried to a moisture level too low for mold growth to occur. Raising the initial moisture content to higher than 40% was not considered satisfactory since the microorganism population that develops on wet forage is governed by the moisture potential. It is doubtful if partially cured hay would be stored at a moisture potential much higher than that found in ground alfalfa hay containing 40% moisture (1). Usually the moisture potential in moist, loose, baled or chopped hay would be less than in ground hay containing 40% moisture. Using a higher initial moisture content probably would result in an entirely different microorganism population than normally found on partially cured hay stored with 30 to 45% moisture.

In the spring of 1954 rubber stoppered Erlenmeyer flasks and 8-ounce, screw-top jars were used to determine if they would maintain the moisture content at a higher level than the cotton stoppered Erlenmeyer flasks. Both the rubber stoppered flasks and the screw-top jars decreased the rate of moisture loss but air exchange was curtailed to a point where it greatly limited the rate of mold growth. The rubber stoppered flasks were not used in further experiments because the screw top jars were less expensive, easier to fill and empty, and required less storage space.

By punching a single 1-mm. hole in the metal cap of the screw top jars, adequate air exchange was obtained, and moisture loss was slowed to about one-third the rate which occurred in the cotton stoppered Erlenmeyer flasks. From this preliminary experiment it appeared that the screw top jars would be superior to the cotton-stoppered Erlenmeyer flasks because they maintained a higher moisture content for a longer period of time.

Chemicals effective in the preliminary testing with cotton-stoppered Erlenmeyer flasks or screw top jars need to be evaluated further in the laboratory before expensive field testing is undertaken. The procedure of rehydrating and inoculating with mold spores after 11 weeks of storage does not appear to be a satisfactory method of making the test more rigorous. It is conceivable that a chemical could be such an effective fungicide that it sterilizes the hay. Such sterilized hay may not become sufficiently reinoculated with mold spores under average mow or stack storage conditions to suffer much mold damage even if the chemical is dissipated or loses its effectiveness early in the storage period. Rewetting and re-contaminating the hay with mold spores after 11 weeks of storage would eliminate any compounds that might be effective in this manner.

More rigorous evaluation of effective compounds might be accomplished in the laboratory by treating hay of 40% moisture with the effective chemicals in the same manner as prescribed for the initial screening, but storing the Erlenmeyer flasks or screw top jars for a period of 6 to 8 months in an incubator capable of being maintained at 25° C. and 85% relative humidity. At this relative humidity, the hay would gradually dry to a moisture content of about 20% (1). This is the moisture content hay reached after 33 weeks when treated in the field with 2,4,6-trichlorophenol at the rate of 1.25%, and baled with 30% moisture (3). Only chemicals that pass such a rigid laboratory test should be considered for expensive field experiments.

Even if a chemical controls the growth of mold in moist hay stored in the stack or mow, consideration must be given to the toxicological problems associated with its use before it can be recommended as a moist hay preservative.

SUMMARY

A large number of chemicals were tested in the laboratory to determine their ability to prevent growth of molds in moist hay.

Seventy grams of coarsely-ground alfalfa hay containing 40% moisture was treated with an experimental chemical and stored in a cotton-stoppered Erlenmeyer flask or an 8-ounce screw top jar with a 1-mm. hole in the cap for 11 weeks. At the end of the storage period the amount of mold growth was estimated visually. Visible mold growth was closely correlated to total loss of dry matter.

Out of approximately 100 chemicals used in these experiments at the rates tested, only one-third of the compounds prevented the appearance of visible mold growth on moist hay stored for 11 weeks. Many of these compounds were effective only at heavy rates of application and do not appear to warrant further testing. The chlorinated phenols, with the exception of pentachlorophenol, were effective when applied at the rate of 0.20 to 0.25%. Since 2,4,6-trichlorophenol is the least expensive of the chlorinated phenols it does not appear that any of the other chlorinated phenols will be superior to it for field treatment of moist hay.

Salicylaldehyde, 5-chlorosalicylaldehyde, several of the halogenated aliphatic carbonyls, and methyl-2,3-dibromopropionate

were effective at low rates of application. The halogenated aliphatic aldehydes and ketones with the higher boiling points were effective at very low rates of application.

The procedure outlined in this paper is sufficiently rigorous to eliminate all but the more promising chemicals as preservatives for moist hay, but compounds which were effective in this test may still fail under field conditions where uniform distribution is difficult to achieve. Compounds which appear promising by this method of screening should be tested further in the laboratory under more carefully controlled conditions and for longer periods of time before subjecting them to expensive field evaluation.

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High Altitude Meadows in Colorado: II. The Effect of Harvest Date on Yield and Quality of Hay[1]

David E. Miller, Forrest M. Willhite, and Hayden K. Rouse[2]

IT HAS been a common practice in the high altitude meadow areas of Colorado to harvest the meadow hay after the greatest possible yields of forage have been obtained, without considering a decline in quality of hay that may occur as a result of advanced maturity.[3]

The experiment reported here was conducted to determine the effect of stage of maturity at harvest on the yield and quality of hay, and to determine the effects of nitrogen and phosphorus fertilization on these relationships. It is recognized that many factors enter into the quality of hay, but in this paper only the percentages of crude protein and total phosphorus are used to evaluate hay quality.

MATERIALS AND METHODS

The study was conducted during 1951 and 1952 near Gunnison, Colo., within the confines of another high altitude meadow experiment.[4] The site was on a relatively well-drained mountain meadow, at an elevation of 7,460 feet. The soil, a loam, was underlain by cobble and covered by a sod mat several inches thick. The principal forage species in the area were smooth bromegrass (*Bromus inermis* Leyss.), Kentucky bluegrass (*Poa pratensis* L.), and alsike clover (*Trifolium hybridum* L.). Small amounts of timothy (*Phleum pratense* L.), sedges (*Carex* spp.), rushes (*Juncus* spp.), and various weeds were also present.

Six dates of harvest were factorially combined with four levels of fertilizer and completely randomized in each of four replications. Each plot was 5 by 6 feet in size, and an area 3 feet square was harvested from each plot.

Harvests began about June 15 of each year and continued at intervals until late August. At the time of the last harvest each year the regrowth on plots previously harvested was also removed. In 1952, samples of smooth bromegrass, Kentucky bluegrass, alsike clover, timothy, sedges, and rushes were collected at each harvest to determine the effect of stage of maturity on the crude protein and total phosphorus percentages in the individual species.

Fertilizer treatments were a non-treated check, nitrogen (NH_4NO_3) at 160 pounds per acre, phosphorus at 200 pounds P_2O_5 per acre (treble superphosphate), and a combination of 160 pounds of nitrogen and 200 pounds P_2O_5 per acre. Nitrogen was applied in the spring of both 1951 and 1952, but phosphorus was applied only in 1951. All fertilizer was applied on the surface in bands 8 inches apart.

The forage was analyzed for crude protein and total phosphorus utilizing the same analytical methods referred to by Rouse, Willhite, and Miller.[4] Hay yields and analytical data are expressed on the basis of hay oven-dried to a constant weight at 70° C.

Prior to the harvest of each plot each year, visual estimates of the major plant species present were made. These estimates were based on the percentage of the total forage volume that appeared to be due to each species.

RESULTS AND DISCUSSION

The stage of maturity at any one time varied greatly within a species because of the variation found in growth rate of the plants on the meadow. As a result, only an approximate stage of maturity can be given for each time of harvest. The approximate maturity stages of the grasses and clovers at the time of each harvest in 1952 were as follows:

Date	Grasses	Clovers
June 17	Inflorescence in sheath stage, some inflorescence had emerged	Budding, with scattered blossoms
June 30	Generally headed, scattered blossoms	Blossoming
July 12	Blossoming	Blossoming, some seed beginning to form
July 28	Seed forming	Seed forming
Aug. 13	Seed formed	Seed formed
Aug. 22	Seed ripening	Seed ripening

[1] Joint contribution of Colorado Agr. Exp. Sta. and Western Soil and Water Management Section, Soil and Water Conservation Research Branch, Agricultural Research Service, U.S.D.A. Authorized by the Director of the Colorado Agr. Exp. Sta. for publication as Scientific Journal Series 449. Rec. for publication Aug. 26, 1954.

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Table 1.—Yields of dry hay* as affected by time of harvest means of all fertilizer treatments.

Initial harvests				Regrowth				Initial harvest plus regrowth			
1951		1952		1951		1952		1951		1952	
Harvest date	Yield tons per acre	Harvest date	Yield tons per acre	Harvest date	Yield tons per acre	Harvest date	Yield tons per acre	Initial harvest date	Yield tons per acre	Initial harvest date	Yield tons per acre
June 12	1.47	June 17	1.50	Aug. 23	2.32	Aug. 22	2.22	June 12	3.79	June 17	3.72
June 25	2.32	June 30	2.32	Aug. 23	1.80	Aug. 22	1.87	June 25	4.11	June 30	4.19
July 18	2.93	July 12	2.90	Aug. 23	1.04	Aug. 22	1.34	July 18	3.97	July 12	4.24
Aug. 2	3.70	July 28	3.39	Aug. 23	0.52	Aug. 22	0.72	Aug. 2	4.23	July 28	4.11
Aug. 8	3.82	Aug. 13	4.11	——	——	——	——	Aug. 8	3.82	Aug. 13	4.11
Aug. 27	4.37	Aug. 22	4.09	——	——	——	——	Aug. 27	4.37	Aug. 22	4.09
Mean	3.10	Mean	3.05	Mean	1.42	Mean	1.54	Mean	4.05	Mean	4.08
LSD (0.05)	0.38		0.38		0.27		0.29		N.S.		N.S.
LSD (0.01)	0.51		0.51		0.36		0.38		N.S.		N.S.

* Oven dried at 70° C.

The stages of maturity were roughly the same in both 1951 and 1952 at comparable dates. The grasses growing where nitrogen fertilizer was applied matured much more slowly than where nitrogen had not been used.

Effect of Maturity on Hay Production

The hay yields of the initial as well as regrowth harvests increased with length of growth period and consequently with plant maturity (table 1). In both 1951 and 1952, the most rapid rates of growth were obtained between the first and second initial harvests. This was during the time of relative immaturity when the plants were developing their inflorescence.

There were no significant differences in the total yields of hay produced if the initial harvests and regrowth are summed, regardless of the time of the initial harvest (table 1). Furthermore, there were no significant interactions between fertilization and time of harvest on the hay yields in either year.

Effects of Maturity on Crude Protein and Total Phosphorus in the Hay

Percentages of crude protein and total phosphorus.—Advancing maturity decreased the percentages of crude protein and total phosphorus in the forage, as shown in tables 2 and 3. In the various species they also declined as the plants became older (figures 1 and 2).

The initial harvests of both 1951 and 1952 showed a significant interaction in percentages of crude protein between fertilization and the time of harvest. Where nitrogen fertilizer had been applied, the crude protein percentages declined much faster with time than where no nitrogen had been used. The interaction was pronounced during the early stages of growth as shown in figure 3, but after about July 31, it was not significant. The data from the samples of smooth bromegrass showed a similar interaction between nitrogen fertilization and harvest time. Kentucky bluegrass did not show such an interaction. The other species were not studied in connection with fertilization.

Table 2.—Percentages and yields of crude protein* as affected by time of harvest means of all fertilizer treatments.

Initial harvests						Regrowth						Initial harvests plus regrowth			
1951			1952			1951			1952			1951		1952	
Harvest date	Per-cent	Yield lbs. per acre	Harvest date	Per-cent	Yield lbs. per acre	Harvest date	Per-cent	Yield lbs. per acre	Harvest date	Per-cent	Yield lbs. per acre	Initial harvest date	Yield lbs. per acre	Initial harvest date	Yield lbs. per acre
June 12	14.0	419	June 17	17.3	534	Aug. 23	12.8	598	Aug. 22	14.4	640	June 12	1017	June 17	1173
June 25	13.5	650	June 30	15.4	728	Aug. 23	13.4	485	Aug. 22	14.9	561	June 25	1135	June 30	1289
July 18	11.6	674	July 12	13.3	786	Aug. 23	16.4	345	Aug. 22	16.3	434	July 18	1019	July 12	1220
Aug. 2	11.6	850	July 28	11.3	778	Aug. 23	16.8	175	Aug. 22	18.3	261	Aug. 2	1025	July 28	1039
Aug. 8	10.8	826	Aug. 13	10.7	882	——	——	——	——	——	——	Aug. 8	826	Aug. 13	882
Aug. 27	9.4	824	Aug. 22	9.6	784	——	——	——	——	——	——	Aug. 27	824	Aug. 22	784
Mean		708	Mean		748	Mean		400	Mean		474	Mean	974	Mean	1065
LSD (0.05)	1.0	101		0.9	97		1.4	96		0.9	103		150		142
LSD (0.01)	1.3	134		1.3	129		1.8	129		1.3	137		199		189

* Based on oven dry (70° C.) hay.

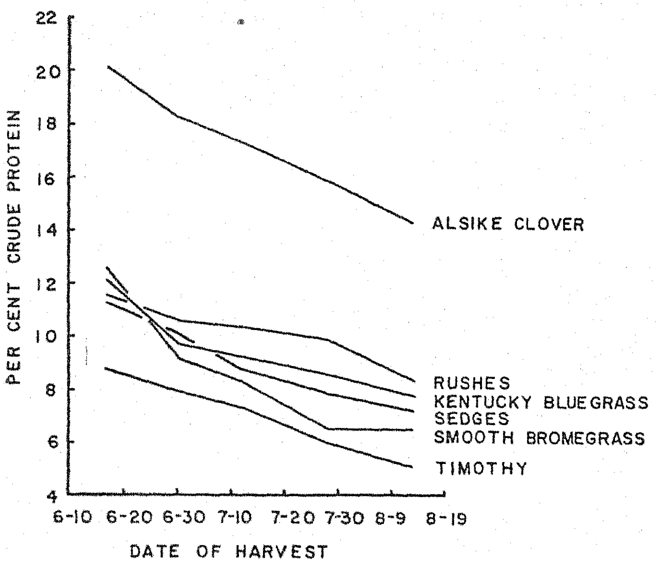

FIG. 1.—Crude protein percentages in plant species as affected by time for harvest, 1952. No fertilization.

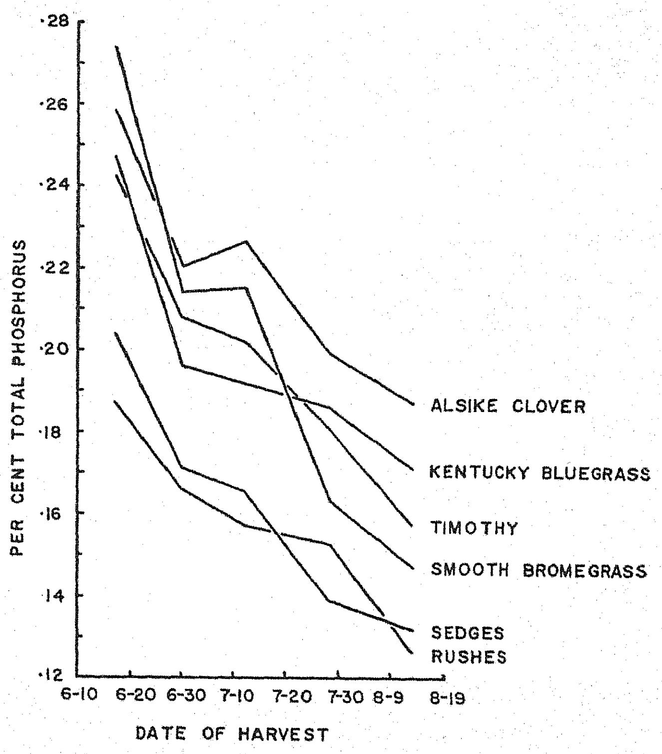

FIG. 2.—Total phosphorus percentages in plant species as affected by time of harvest, 1952. No fertilization.

An idea of the relative feeding value of the major species in the area may be obtained by comparison of the data in figure 1. Ranchers have expressed the opinion that cattle will thrive better on wire grass hay (rushes) than on timothy or smooth bromegrass hay. The ranchers' idea is supported by the data in figure 1 showing the rushes to be considerably higher in crude protein than timothy and smooth bromegrass.

Yields of crude protein and phosphorus.—The yields of both crude protein and phosphorus from the initial harvests increased with the maturity of the forage until near the end of the growing season in both years (tables 2 and 3). At this time a net loss of both was indicated, although the only significant loss was in crude protein in 1952.

The data from the initial harvests of both years show two periods of rapid increase with time in yields of crude protein and phosphorus. The first such period occurred in the spring from approximately the time of stem elongation and inflorescence development until blossoming had begun. The second period of increasing protein and phosphorus yields occurred during the time of seed formation and maturation. During the time between these two periods, which was roughly the time of being in blossom, rather constant yields of both constituents are indicated.

The largest total yields of phosphorus and crude protein from the regrowth and initial harvests combined were

Table 3.—Percentages and yields of phosphorus* as affected by time of harvest means of all fertilizer treatments.

Initial harvests						Regrowth						Initial harvests plus regrowth			
1951			1952			1951			1952			1951		1952	
Harvest date	Per-cent	Yield lbs. per acre	Harvest date	Per-cent	Yield lbs. per acre	Harvest date	Per-cent	Yield lbs. per acre	Harvest date	Per-cent	Yield lbs. per acre	Initial harvest date	Yield lbs. per acre	Initial harvest date	Yield lbs. per acre
June 12	0.288	8.53	June 17	0.268	8.00	Aug. 23	0.256	11.83	Aug. 22	0.269	11.83	June 12	20.36	June 17	19.83
June 25	.278	13.11	June 30	.247	11.30	Aug. 23	.277	9.91	Aug. 22	.299	11.09	June 25	23.03	June 30	22.39
July 18	.235	13.65	July 12	.230	13.33	Aug. 23	.332	6.93	Aug. 22	.335	8.96	July 18	20.58	July 12	22.28
Aug. 2	.238	17.48	July 28	.199	13.33	Aug. 23	.326	3.41	Aug. 22	.362	5.22	Aug. 2	20.90	July 28	18.55
Aug. 8	.219	16.63	Aug. 13	.181	14.71	——	——	——	——	——	——	Aug. 8	16.63	Aug. 13	14.71
Aug. 27	.198	17.16	Aug. 22	.176	14.18	——	——	——	——	——	——	Aug. 27	17.16	Aug. 22	14.18
Mean		14.50	Mean		12.47	Mean		8.00	Mean		9.28	Mean	19.83	Mean	18.66
LSD (0.05)	.016	1.81		.013	1.60		.020	1.60		.023	1.49		2.56		2.24
LSD (0.01)	.021	2.45		.018	2.13		.026	2.13		.031	2.03		3.41		2.99

* Based on oven dry (70° C.) hay.

obtained when the initial harvest was taken in late June (tables 2 and 3). With this combination, dry matter yields as well as percentages of crude protein and phosphorus were relatively high from both regrowth and initial cuts. When no significant differences occurred in the total yields of dry hay, the high contents of protein and phosphorus became important in determining the yields of these two constituents.

Interactions between fertilization and date of harvest were not significant with respect to yields of crude protein and phosphorus in either the initial harvests or the regrowth.

Effect of Time of Harvest on Species Composition

As shown in figures 1 and 2, there were large variations in crude protein and phosphorus percentages among the various plant species. Changes in the species stands that might result from the various date of harvest practices may become important in the evaluation of these practices.

The changes in species composition were not fully determined in this study because the period of time covered was not sufficient to allow major changes to occur and the original species composition was extremely variable. However, changes that were observed in stands of smooth bromegrass and clovers, and which seem worthy of record are shown in table 4.

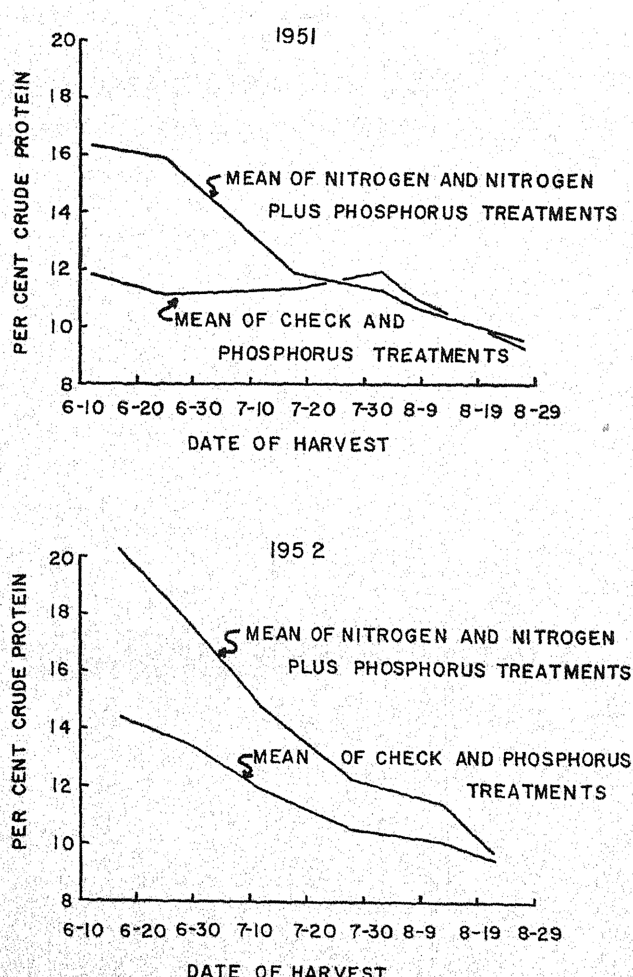

FIG. 3.—Crude protein percentages in hay as affected by nitrogen fertilization and time of harvest.

Table 4.—Effect of time of harvest and nitrogen fertilization on species composition of mountain hay meadows—based on 1952 estimates.

Fertilizer treatments*	Time of initial harvest in 1951					
	June 12	June 25	July 18	Aug. 2	Aug. 8	Aug. 27
	% Smooth Bromegrass					
O-P	18	12	14	18	26	29
N-NP	40	33	46	61	58	57
	% Clovers (All clover species together)					
O-P	37	45	51	34	44	39
N-NP	15	11	6	2	3	2

* O-P Mean of estimates of check and phosphorus treatments.
N-NP Mean of estimates of nitrogen and nitrogen plus phosphorus treatments.

The effect of time of harvest is more pronounced when considered with fertilization effects. Where no nitrogen fertilizer had been applied, the forage contained approximately 35 to 50% clovers, with the harvest time having but little effect on the clover stands. Where nitrogen fertilizer had been used and late harvesting practiced as well, the clovers were practically eliminated and the forage was predominantly grasses. Phosphorus fertilization did not have any apparent effect on the species composition.

It is difficult to make any definite statements regarding the minor species because their estimates could easily be influenced by the competition offered by the predominating species.

SUMMARY

An experiment was conducted on a high altitude hay meadow near Gunnison, Colo., to determine the effects of harvesting at different stages of maturity on the yields of hay, percentages and yields of crude protein and percentages and total uptakes of phosphorus. Use of nitrogen and phosphorus fertilizers was also studied.

The data indicate that the plants continue to increase in dry weight throughout the season. However, when forage was harvested early in the season and the regrowth included in the total yield of hay, there were no significant differences in the total hay produced regardless of the time of the initial harvest.

The forage tended to become lower in percentages of crude protein and total phosphorus as it became more mature.

The data indicate that yields of crude protein and total phosphorus uptake continue to increase until near the end of the growing season. The greatest total crude protein yields and phosphorus uptake, summing the regrowth and initial harvests, was obtained where the initial harvest occurred near the end of June.

Delaying the time of harvest had greater effect in decreasing the crude protein percentages in the forage where nitrogen fertilizer had been applied than where it had not been used.

The species composition was affected by the time of harvest and fertilization. Grasses were encouraged and clovers were depressed by combining late harvesting and nitrogen fertilization.

Dry Matter and Nitrogen Yields of Legume Tops and Roots in the Fall of the Seeding Year[1]

H. A. Fribourg and I. J. Johnson[2]

ALTHOUGH the use of legumes plowed under for green manure is one of our oldest agricultural practices, there is a surprising lack of information in the literature on the critical evaluation of legume species with respect to differences in yields of dry matter or nitrogen, and nitrogen percentages. Numerous investigators[3,4] (1, 4, 9, 10, 11, 12) have recorded the pounds of dry matter and yield of nitrogen per acre for sweetclover at the end of the seeding year. A few investigations (2, 6, 7, 13) have been made to compare red clover and alfalfa, or to contrast these legumes with sweetclover, but no studies were found reporting on the comparative value of strains of alfalfa and Ladino clover.

With changes in seed production practices and greater availability of Ladino clover and Southern common alfalfa, it seemed desirable to evaluate these legumes in comparison with biennial and annual sweetclovers, medium red clover and Northern-grown alfalfa, which have been in more common use as sources of green manure crops planted with oats. The data to be presented in this report are limited to comparisons of the legumes in the fall of the seeding year. The effects of these legumes on the subsequent yields of corn in the rotation will be reported in a later paper.

MATERIALS AND METHODS

Seedings of Madrid and Hubam sweetclovers, Grimm and Southern-grown common alfalfas, and Ladino and medium red clovers were made at four locations in Iowa in the springs of 1951 and 1952. The experimental sites at Ames, Clarinda, Kanawha and Marcus, were located on Nicollet loam–Webster silty clay loam intergrade, Marshall silt loam, Nicollet–Webster intergrade, and Marcus silty clay loam–Primghar silt loam intergrade, respectively. The soils at each location either had been limed or had a pH value of 6.2 or above. The legumes were seeded at the rate of 70 viable seeds per square foot. At all locations, liberal applications of phosphorus and potassium fertilizers were broadcast in the spring and disked in. The oat companion crops were combined at maturity.

A randomized complete block design with four replications was used at all locations. Each plot measured 13 ft., 4 in. by 23 ft., 4 in. Following a killing frost in the fall of the seeding year, samples were obtained from the legume seedings to determine yields of tops and roots. In 1951, 2 quadrats measuring 18 in. by 36 in. were taken in each legume plot; in 1952, 4 quadrats, 18 in. by 18 in., were used. The method followed for uplifting root samples from the soil, and the subsequent washing treatment, have been presented earlier (5). Roots were sampled to a maximum depth not exceeding 2½ ft.

After washing, the tops and roots were dried in a 70° C.-oven, and weighed. The top and root samples from a particular plot were then composited separately and ground in a Wiley mill to pass a 40-mesh sieve in preparation for subsequent chemical analysis. Total nitrogen contents of roots and tops were measured by means of Winkler's modification of the Kjeldahl method (10). A 1.5 gm. sample of plant material was used.

RESULTS AND DISCUSSION

In 1951, severe attacks of sweetclover weevil drastically reduced stands of the sweetclovers, and summer black stem seriously damaged the alfalfas. As a result, the dry matter yields of these four legumes were low (table 1). On the other hand, stands of medium red clover and Ladino clover were excellent and were favored by a moist and cool spring. Total (tops plus roots) dry matter yields of medium red and Ladino clovers were in general above 1 ton per acre, and were over 1½ tons in the case of Ladino clover at 2 locations. In 1952, good stands of all legumes were obtained. Total dry matter yields of Madrid sweetclover varied between 2 and 3 tons per acre. Alfalfa yields were above 1 ton and attained as much as 2 tons at 1 location. The differences between Grimm and Southern common alfalfas were nonsignificant. The 1952 season was characterized by severe mid-summer and early fall drought. Under these conditions, Ladino clover yields compared favorably with those obtained the previous year, ranging between 1 to almost 1½ tons per acre. Hubam sweetclover yields were considerably lower than those of biennial sweetclover. Yields of this legume probably were underestimates of the seasonal growth, since sampling was carried out at a time when most leaves and some stem branches of Hubam had already fallen off the plants. Medium red clover yielded from less than ½ to slightly over 1 ton dry matter per acre, and was less productive than Ladino clover at all locations in the 1952 season.

The top-root ratios for dry matter yields are presented in table 2. Madrid sweetclover and the 2 alfalfas had top-root ratios varying between 1 and 3, with only 2 exceptions. The 1951 ratios for these legumes were higher at those locations where yields also were larger. However, when stands and yields were excellent, the ratios decreased to between 1.36 and 1.67. Medium red clover top-root ratios generally were higher than those for alfalfas, and ranged between less than 2 to almost 4. Ladino clover had a higher top-root ratio than medium red clover, as would be expected in the light of the growth habit of the plant and since stolons were included in the "top" portion. The very high top-root ratios for Hubam sweetclover emphasized the poor root growth and development of this annual legume.

The nitrogen percentages of tops (table 3), including crowns or stolons, varied with the season, species, and location. At Kanawha and Marcus, the nitrogen percentages were higher than at the other two locations. This higher nitrogen content was associated, in 1951 particularly, with higher total dry matter yields. The alfalfas and clover had an average nitrogen content approaching 3%, as also was the case in 1951 for Madrid sweetclover. When the yield of the latter legume was high, the average nitrogen content of tops decreased to 2.6%. Hubam sweetclover nitrogen contents varied according to the percentage of the leaves shed by the time of sampling. Root nitrogen contents (table 4)

[1] Journal Paper No. J-2584 of the Iowa Agr. Exp. Sta., Ames, Iowa. Project 1205. Received for publication Aug. 27, 1954.

[2] Graduate Assistant in Farm Crops and Professor-in-Charge of Farm Crops, respectively, in the Agronomy Department, Iowa State College.

[3] Burnett, Kenneth H. Experiments on fall clipping of sweet clover. M.S. thesis, Iowa State College. 1938.

[4] Hawk, Virgil B. The effect of clipping on the yield and nitrogen content of sweetclover. M.S. thesis. State College of Washington. 1938.

Table 1.—Total* dry matter yields (pounds per acre) of six legumes harvested in the fall of the seeding year.

Location	Grimm alfalfa	Southern common alfalfa	Madrid sweet-clover	Hubam sweet-clover	Medium red clover	Ladino clover
			1951 Season			
Ames	383	427	911	348	2023	2935
Clarinda	553	452	858	227	2148	1771
Kanawha	1838	2076	1150	289	2425	3182
Marcus	1185	868	343	173	2305	3479
Average	990	956	816	259	2225	2842
			1952 Season			
Ames	2238	2649	4953	1670	1745	2867
Clarinda	2694	2465	6325	2302	838	1955
Kanawha	3030	2684	4502	3201	1873	2668
Marcus	3900	4287	4815	2716	2217	2934
Average	2966	3021	5149	2472	1668	2606

* Total yield refers to the sum of top plus root yields.

were lower than those for tops, except in the case of Madrid sweetclover. At most locations in both seasons, nitrogen percentage in biennial sweetclover roots was equal to or larger than the nitrogen percentage in tops. Although location and season effects accounted for much of the variation in nitrogen contents of roots, the wide range noted in the case of tops was not as prevalent for the subterranean portions of the plants.

The total nitrogen yields of the six legumes have been tabulated in table 5. The effects of sweetclover weevil and summer black stem were reflected not only in low dry matter yields for 1951, but also in low total nitrogen yields. However, when good stands were obtained, the total nitrogen yields closely approximated those found elsewhere by other investigators. In 1952, Madrid sweetclover yielded 135 to 150 pounds of nitrogen per acre and the alfalfas produced from 60 to almost 120 pounds per acre. Grimm and Southern alfalfas were not significantly different in nitrogen yield. Although the dry matter yields of Ladino clover were not as high as those of other legumes, the nitrogen production of this legume was good in both years. In either a cool and moist year (1951) or a season characterized by mid-summer and fall drought (1952), Ladino clover yielded from 70 to over 100 pounds of nitrogen per acre, with the exception of one instance when the yield was only about 50 pounds. This latter yield was obtained at Clarinda, in southwestern Iowa, which was warmer and drier than other sections of the state. In one test in 1951, medium red clover was superior to Ladino, but in general the nitrogen yields of red clover were lower than those of Ladino clover, and ranged between 30 and 70 pounds per acre. Hubam sweetclover yields in 1952 were above 70 pounds per acre at 2 locations; at the other 2, late fall sampling measured only from 25 to 30 pounds of nitrogen per acre.

The correlations between nitrogen percentages and dry matter yields for all legumes, locations and years were 0.014 for tops and 0.412 for roots. Only the latter value exceeded the 5% level of significance. Analysis of variance of the nitrogen yield data for each season indicated significant differences at the 1% level for locations, legumes, and the legume × location interactions. In 1951, the standard error was 11.2 and the coefficient of variability 28.1%; the second year, the standard error was 14.5 but the coefficient of variability only 17.9. Further analysis of the 1952 data suggested that the use of a larger number of replications with fewer samples per plot would have increased the relative efficiency for yield measurements of legume roots and tops, assuming that the total of 16 samples used was the maximum possible for each legume.

Since both root sampling and total nitrogen analyses require a large expenditure of labor, time and money, it would be advantageous to arrive at an estimate of the information

Table 2.—Top-root ratios for dry matter yields of six legumes harvested in the fall of the seeding year.

Location	Grimm alfalfa	Southern common alfalfa	Madrid sweet-clover	Hubam sweet-clover	Medium red clover	Ladino clover
			1951 Season			
Ames	1.57	2.48	1.32	7.30	2.25	3.58
Clarinda	.96	1.64	1.18	5.31	2.04	2.97
Kanawha	2.17	3.62	1.53	7.04	3.66	2.78
Marcus	2.06	3.54	3.02	8.84	2.79	3.27
Average	1.69	2.82	1.76	7.12	2.68	3.15
			1952 Season			
Ames	1.32	1.48	1.29	5.20	2.31	4.64
Clarinda	1.10	1.35	1.67	8.63	1.76	5.20
Kanawha	1.62	2.20	2.10	17.83	3.83	10.02
Marcus	1.38	1.52	1.62	3.74	2.69	4.06
Average	1.36	1.64	1.67	8.85	2.65	5.98

Table 3.—Nitrogen percentages of tops (including crowns or stolons) of six legumes harvested in the fall of the seeding year.

Location	Grimm alfalfa	Southern common alfalfa	Madrid sweet-clover	Hubam sweet-clover	Medium red clover	Ladino clover
			1951 Season			
Ames	3.07	2.98	2.63	2.02	2.72	3.18
Clarinda	2.90	2.70	2.52	2.15	2.90	2.84
Kanawha	3.35	3.35	3.53	3.07	3.10	3.41
Marcus	3.34	3.28	3.36	2.56	3.09	3.13
Average	3.16	3.08	3.01	2.45	2.95	3.14
			1952 Season			
Ames	3.02	2.74	2.30	1.42	2.69	3.04
Clarinda	2.70	2.70	2.15	1.28	3.09	2.71
Kanawha	3.48	3.34	2.85	2.83	3.36	3.23
Marcus	3.37	3.10	3.06	2.62	3.22	2.79
Average	3.14	2.97	2.59	2.04	3.09	2.94

Table 4.—Nitrogen percentages of roots (excluding crowns) of six legumes harvested in the fall of the seeding year.

Location	Grimm alfalfa	Southern common alfalfa	Madrid sweet-clover	Hubam sweet-clover	Medium red clover	Ladino clover
			1951 Season			
Ames	2.50	2.06	2.51	1.90	2.38	2.10
Clarinda	1.97	1.62	1.56	1.57	2.63	2.32
Kanawha	3.64	3.34	3.76	2.53	3.23	3.28
Marcus	2.61	1.90	2.92	1.43	2.44	2.28
Average	2.68	2.23	2.69	1.86	2.67	2.50
			1952 Season			
Ames	2.57	2.27	3.36	2.33	2.20	2.46
Clarinda	2.46	1.99	2.86	1.92	2.16	2.07
Kanawha	2.75	2.44	3.42	1.14	2.35	2.30
Marcus	2.72	2.42	2.52	2.47	2.41	2.27
Average	2.62	2.28	3.04	1.96	2.28	2.28

Table 5.—Total* nitrogen yields (pounds per acre) of six legumes harvested in the fall of the seeding year.

Location	Grimm alfalfa	Southern common alfalfa	Madrid sweet-clover	Hubam sweet-clover	Medium red clover	Ladino clover
			1951 Season			
Ames	11.3	11.5	24.7	7.4	53.2	85.8
Clarinda	13.3	10.6	17.5	4.7	60.5	47.5
Kanawha	63.0	69.5	41.3	8.7	75.5	106.8
Marcus	36.5	26.4	11.0	4.1	66.9	102.3
Average	31.0	29.5	23.6	6.2	64.0	85.6
			1952 Season			
Ames	63.2	67.3	137.0	26.9	44.6	83.7
Clarinda	70.4	59.5	153.6	31.7	23.2	50.9
Kanawha	96.9	82.0	136.6	88.1	58.6	83.9
Marcus	119.1	119.5	136.2	69.9	66.4	77.3
Average	87.4	82.1	140.8	54.2	48.2	74.0

* Total yield refers to the sum of top plus root yields.

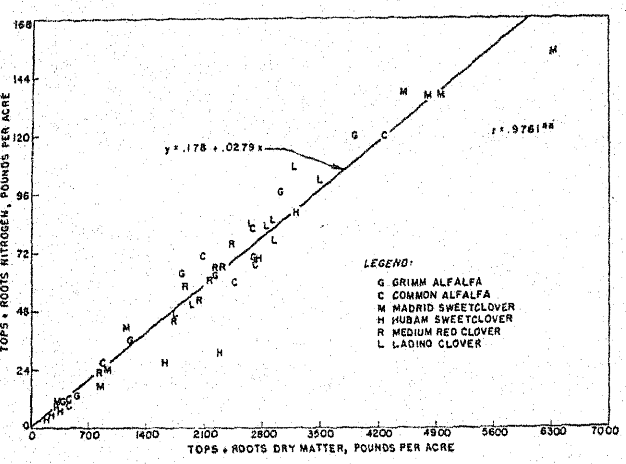

FIG. 1.—Relationship between total (tops plus roots) dry matter yield and total nitrogen yield of six legumes grown in Iowa in 1951 and 1952.

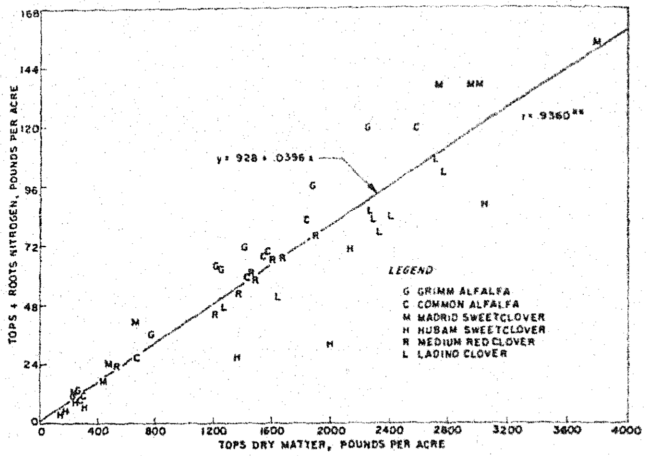

FIG. 2.—Relationship between yield of dry matter in the tops and total (tops plus roots) nitrogen yield of six legumes grown in Iowa in 1951 and 1952.

obtained from these two processes through other means. The relationship between total dry matter production and total nitrogen yield is presented graphically in figure 1. Each point, represented by the appropriate symbol for a particular legume, refers to the mean yield of dry matter and nitrogen of that legume at one location and in one season. The very high correlation (0.976) obtained between total dry matter yield and total nitrogen yield for all legumes, as well as the fact that the regression equation, for all practical purposes, intersected the ordinate at the origin, indicates that total dry matter yield measurements also were good estimates of nitrogen yield of tops and roots.

The relationship between dry matter yield of the tops alone and the total nitrogen yield in the tops and roots is represented in a similar way in figure 2. Although more scatter was evident in this graph, again the correlation coefficient was above 0.9 and the regression equation intersected the ordinate at the origin. It seems, therefore, that estimates of dry matter yields of legume tops in the fall of the seeding year, when the stems are severed from the roots just below the crown (about 1 inch below ground level), also are reasonably good estimates of nitrogen yields of tops and roots. Further corroboration is necessary to determine whether this relationship holds under widely different environmental conditions and on other soils.

SUMMARY AND CONCLUSIONS

A study was made to determine the dry matter and nitrogen yields of the tops and roots of six legumes grown at four locations in Iowa in 1951 and 1952 when harvested in the fall of the seeding year. Stands, and hence yields, of legumes were affected by disease and sweetclover weevil in 1 year, while in the second year good stands of all seedings were obtained. Total dry matter yields (tops plus roots) of Ladino and medium red clovers in 1951 were about 1½ tons per acre, while alfalfas and sweetclovers yielded ½ ton or less per acre. In 1952, Madrid sweetclover yielded 2½ tons dry matter per acre, alfalfas about 2 tons, Ladino clover 1½ tons, and red clover between 1 and 1½ tons per acre. Hubam sweetclover yields were low in both years at most locations as a result of the annual growth habit of the species and because sampling was carried out after leaf and some stem losses had occurred. Grimm and the strain of Southern common alfalfa were not significantly different in either dry matter yields or nitrogen contents.

Nitrogen percentages of legume tops or roots did not vary significantly among species. Nitrogen yields, however, varied widely among legumes because of the variations in dry matter yields. When good stands were obtained, Madrid sweetclover yielded 135 to 150 pounds of nitrogen per acre, alfalfas yielded between 60 and 120 pounds, Ladino clover between 50 and 110 and medium red clover between 35 and 80 pounds of nitrogen per acre in tops and roots. The variations observed within legumes were due to the effects of both location and season.

Madrid sweetclover root yields were nearly equal to the top yields. Alfalfa top-root ratios were slightly higher than those for biennial sweetclover. Red clover top-root ratios were about 1.8 to 3.8, whereas those for Ladino clover were somewhat higher.

A correlation of 0.976 was obtained between total dry matter yield and total nitrogen yield for all legumes at all locations for both years. The correlation for all legumes between dry matter yield of tops (cut at the crown) and total nitrogen yield was 0.936. The latter relationship between top growth and total nitrogen yield lends confidence to the possible evaluation of legumes, in the fall of the seeding year, in terms of top yields alone.

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Fertilizer Value of Rhenania-Type Phosphates in Greenhouse Experiments[1]

E. J. Brenes, R. Miller, and W. R. Schmehl[2]

RESULTS obtained in a recent investigation carried out by the Colorado Agricultural Experiment Station (7) indicated that Rhenania-type phosphate, a finely ground, very slightly water-soluble material, was as available to various crops grown in two calcareous Colorado soils as concentrated superphosphate. The Rhenania-type materials used in the study were ground to pass from 75 to 78% through a 200-mesh sieve. They were found to be less effective when placed in a band than when broadcast and plowed under, a fact which indicated the possibility that this fertilizer's efficiency may be decreased if applied in a granular form. These results merit additional study of the availability of Rhenania-type phosphates in calcareous soils.

The greenhouse experiments reported herein had two objectives:

(1) To ascertain the relative availability of finely ground Rhenania-type phosphate and concentrated superphosphate in six western soils, and

(2) To study the effect of granulation of Rhenania-type phosphate upon the availability of the fertilizer.

MATERIALS AND METHODS

Phosphate Source Study

A greenhouse experiment using Siberian millet as the test crop was conducted on six western soils of varying textures and lime content. For the description of the soils used see table 1.[3] Each soil was air-dried, screened through a 2-mm. sieve and thoroughly mixed to insure homogeneity. Various phosphate materials were tested but only the results obtained with concentrated superphosphate and a finely ground Rhenania-type phosphate are reported here.[4] The fertilizer materials were applied at the rates of 0, 50, and 200 pounds of P_2O_5 per 2,000,000 pounds of soil by intimately mixing corresponding amounts of soil and fertilizer in a twin-shell blender. Twenty-two hundred grams of treated soil were then placed in a ½-gallon cardboard container; each treatment was replicated four times. The soil was maintained at moisture equivalent for 19 days, air-dried, and planted. Sufficient nitrogen and potassium were added to preclude the occurrence of deficiencies in these nutrients. Twelve seeds were planted in each pot and subsequently thinned to seven plants. Adequate moisture was maintained throughout the entire growing period by bringing the soils to moisture equivalent every other day. After 49 days the plants were harvested by cutting the culms just above the crowns. The plant material was dried in a forced draft oven at 70° C. The weight of oven-dry matter was ascertained and the plant material was then ground in a Wiley mill to pass a 40-mesh screen. The phosphorus content of the plant material was determined colorimetrically as molybdivanadophosphoric acid (1) after digestion with a perchloric-sulfuric acid mixture. The available P_2O_5 in the soil was determined as pounds P_2O_5 per 2,000,000 pounds of soil soluble in 0.5 *M* $NaHCO_3$ (6).

The yield of dry matter, total phosphorus uptake, and the available phosphorus in the soil at the conclusion of the experiment were used as means for judging the availability of the phosphorus in the fertilizers.

Granulation Studies

Two greenhouse experiments utilizing two different soils and granulated Rhenania-type phosphate of varying granule sizes were

[1] Contribution from the Agronomy Section, Colorado Agr. Exp. Sta. The work was supported in part by a fellowship grant from the Ideal Cement Co. Authorized by the Director of the Colo. Agr. Exp. Sta. for publication as Scientific Journal Series No. 447. Rec. for publication Aug. 30, 1954.

[2] Graduate assistants and Associate Agronomist.

[3] The writers wish to express their appreciation to the following individuals for supplying soils utilized in this study:
Dr. W. H. Fuller, Arizona Agr. Exp. Sta.; Mr. Lionel Harris, Scottsbluff, Nebraska Exp. Farm; Dr. R. L. Hausenbuiller, Washington Agr. Exp. Sta.; Dr. W. E. Larson, Montana Agr. Exp. Sta.; and Dr. H. B. Peterson, Utah Agr. Exp. Sta.

[4] The Rhenania-type phosphate was a product of German manufacture, ground to pass 90% through a 100-mesh sieve and 75% through a 200-mesh sieve. It contained 0.26% water soluble and 23.8% ammonium citrate soluble P_2O_5.

Table 1.—Description of soils used in phosphate-source availability study.

Location	Soil	Percent $CaCO_3$	pH	Percent organic matter
Arizona	Mojave sandy loam	0.2	7.6	0.44
Colorado	Berthoud clay loam	2.0	7.8	1.81
Montana	Pryor silty clay	0.7	7.7	1.69
Nebraska	Trip very fine sandy loam	0.2	7.4	1.50
Utah	Millville silty clay loam	13.7	8.3	2.50
Washington	Sagemoor sandy loam	3.3	8.0	0.66

carried out. In one of the tests, a Fort Collins loam was used with Colsess barley as the test crop. The soil contained 3.0% $CaCO_3$ and had a pH of 7.9. The granulated Rhenania-type phosphate was prepared from an experimental product manufactured by the Ideal Cement Co. containing 23.5% ammonium citrate-soluble and 0.08% water-soluble P_2O_5 and was ground to pass 80% through a 180-mesh sieve. Four granule sizes were tested: −180, −90+180, −16+50, and −4+16-mesh.[5] The availability of the phosphate in the two coarser materials was tested for three different degrees of granule hardness classified by the manufacturer as soft, medium, or hard, according to the ease with which the granules disintegrated when immersed in water. The granules were well rounded with the exception of those in the hard −16+50-mesh material which were irregular in shape.

After preparing the soil in a manner similar to that followed in the source study, the materials were applied at a rate of 60 pounds citrate-soluble P_2O_5 per 2,000,000 pounds of air-dry soil. In mixing, care was taken to avoid crumbling the granules. Two thousand grams of soil from each treatment were placed in a ½-gallon cardboard container and maintained at moisture equivalent for a week before planting. Each treatment was replicated four times. Twelve seeds were planted in each pot, but after germination, the pots were thinned to contain 10 plants. Nitrogen was added to insure a sufficiency of the element. The soil used did not require additional potassium. Watering was accomplished by bringing the soil to moisture equivalent every other day.

After 106 days the plants were harvested, oven-dried, weighed, and analyzed for phosphorus content by the same procedures used in the phosphate-source experiment.

[5] The granulated Rhenania-type phosphates were supplied by G. W. Wilsnack, Research Director, Ideal Cement Co., LaPorte, Colo. They were prepared from the finely gound material by moistening with water and redrying in a kiln at varying temperatures.

The second experiment was conducted in Terry sandy clay loam containing 0.9% $CaCO_3$ and having a pH of 7.2. The yield of dry matter of Dakota Kursk millet was used as the criterion for measuring the availability of phosphorus from the granulated materials. Eight granule sizes, +5, −5+9, −5+20, −9+20, −20+60, −20+180, −60+180, and −180-mesh, were separated from an experimental granulated material supplied by the Ideal Cement Co.[6] The granules were well rounded and although rather resistant to crumbling when squeezed between the thumb and forefinger, they fell apart readily when immersed in water.

The different granule sizes were applied at a rate of 80 pounds citrate soluble P_2O_5 per 2,000,000 pounds of air-dry soil. After careful mixing of the material with the soil to avoid destruction of the granules, 4,000 gm. of treated soil were placed in a 1-gallon, lacquered tin can. Each treatment was replicated four times. The soil was maintained at moisture equivalent for a week before planting. Nitrogen and potassium were added to provide adequate amounts of these nutrients. Five plants were grown per pot. After a growing period of 50 days, the plants were harvested and oven-dried.

RESULTS AND DISCUSSION

Phosphate Source Study

The oven-dry weights of Siberian millet and total phosphorus uptake by plants as influenced by source of phosphorus and rate of application are summarized in table 2. The addition of either Rhenania-type phosphate or concentrated super-

[6] The granulated material was prepared from the finely ground fertilizer using ½% black strap molasses as the binding agent.

Table 2.—Average oven-dry weight and phosphorus uptake for millet as influenced by source and rate of phosphate.

Soil	Phosphate material	Yield of dry matter gm. per pot				Phosphorus uptake in mgm. P per pot			
		Pounds P_2O_5 applied per acre			Average for materials	Pounds P_2O_5 applied per acre			Average for materials
		0	50	200		0	50	200	
Mojave	No phosphorus	7.48	—	—	7.48	13.4	—	—	13.4
	Rhenania-type phosphate	—	9.83	9.95	9.89	—	23.1**	26.8	25.0*
	Concentrated superphosphate	—	8.90	9.47	9.18	—	16.5	28.7	22.6
Berthoud	No phosphorus	5.89	—	—	5.89	8.8	—	—	8.8
	Rhenania-type phosphate	—	6.97	8.93*	7.95	—	11.2	10.8	11.0
	Concentrated superphosphate	—	6.74	7.27	7.00	—	10.0	10.2	10.1
Pryor	No phosphorus	1.49	—	—	1.49	1.8	—	—	1.8
	Rhenania-type phosphate	—	5.47	8.29	6.88	—	7.5	9.7	8.6
	Concentrated superphosphate	—	4.93	8.45	6.45	—	6.5	10.1	8.3
Tripp	No phosphorus	6.35	—	—	6.35	7.9	—	—	7.9
	Rhenania-type phosphate	—	8.11	9.68	8.89	—	9.5	18.1	13.8
	Concentrated superphosphate	—	8.31	9.38	8.84	—	11.8	18.2	15.0
Millville	No phosphorus	2.49	—	—	2.49	3.0	—	—	30.
	Rhenania-type phosphate	—	8.20	11.60	9.90	—	10.7	20.3	15.5
	Concentrated superphosphate	—	9.38	11.30	10.34	—	12.8	20.3	16.5
Sagemoor	No phosphorus	1.87	—	—	1.87	2.0	—	—	2.0
	Rhenania-type phosphate	—	7.08	8.73	7.90	—	9.4	15.6	12.5
	Concentrated superphosphate	—	7.01	7.81	7.41	—	9.6	14.1	11.8
L.S.D. 0.05			1.36		0.96		3.22		2.3
L.S.D. 0.01			1.80		1.22		4.26		3.2
Average for six soils:									
	No phosphorus	4.26	—	—	4.26	6.2	—	—	6.2
	Rhenania-type phosphate	—	7.61	9.53*	8.57	—	11.9	16.9	14.4
	Concentrated superphosphate	—	7.55	8.95	8.25	—	11.2	16.9	14.1
	L.S.D. 0.05		0.55		0.33		1.3		0.8
	L.S.D. 0.01		0.73		0.52		1.7		1.2

* Significantly higher at the 5% level than corresponding value for concentrated superphosphate.
** Significantly higher at the 1% level than corresponding value for concentrated superphosphate.

phosphate increased the yield of dry matter and phosphorus uptake in all the soils.

The average values of yield of millet and phosphorus uptake for the 6 soils at the 2 rates of phosphate application were, respectively, 8.57 gm., and 14.4 mgm. for the Rhenania-type phosphate and 8.25 gm., and 14.1 mgm. for the concentrated superphosphate. The difference between yields or phosphorus uptake for the 2 phosphate materials was not significant although the difference in yields closely approached significance at the 5% level.

Occasionally, significant differences occurred between corresponding values for the phosphate materials in individual soils and rates of application. In the Berthoud soil, the yield of oven-dry matter produced by the 200-pound rate of Rhenania-type phosphate was significantly larger at the 5% level than the yield obtained from the equivalent application of concentrated superphosphate. Also, the uptake of phosphorus from the treatment receiving the 50-pound application of Rhenania-type phosphate in the Mojave soil was significantly greater at the 1% level than the phosphorus uptake from the same P_2O_5 rate of concentrated superphosphate. The low values for the concentrated superphosphate treatments were not consistent with other results for the same soils.

When the averages for yield on the six soils were compiled, there was a significant difference between fertilizer sources at the high rate of application. The average uptake of phosphorus in the Mojave soil was significantly greater from Rhenania-type phosphate than from concentrated superphosphate. In both averages the higher values for the Rhenania-type phosphate were largely the result of the individual differences previously mentioned.

The available soil phosphorus values obtained at the conclusion of the experiment on composite samples of the four replications from each treatment are tabulated in table 3. For all soils and rates of phosphate, the application of either phosphate material increased the available phosphorus to about the same level.

The results obtained in this study are in agreement with results obtained in field studies (7) in which finely ground Rhenania-type phosphate was found to be as effective a source of phosphorus as concentrated superphosphate when the fertilizer was plowed under.

The fact that water-insoluble Rhenania-type phosphate compares favorably with concentrated superphosphate as a source of phosphorus in calcareous soils such as those used in this study indicates that the water-solubility of a phosphatic fertilizer should not be the sole criterion for its suitability for use in calcareous soils. Perhaps better means for judging its suitability would be to consider also: *(1)* the end product or products of the reaction it undergoes when incorporated with the soil, *(2)* particle size of the fertilizer, and *(3)* method used in its application as discussed in an earlier study (7).

Lea and Nurse (5) and Franck, *et al.* (4) reported that Rhenania-type phosphates were solid solutions of $CaNaPO_4$ with Ca_2SiO_4. The compound $CaNaPO_4$, the phosphate fertilizer component in Rhenania-type fertilizers, was the subject of a study by Blanc (2). This worker indicated that $CaNaPO_4$ was hydrolyzed by hot water in the presence of CO_2 into di- and trisodium phosphates and neutral and basic calcium phosphates. He indicated also that hydrolysis was rapid when the pH of the medium was maintained around 8 and 9.

Table 3.—Available soil phosphate as influenced by source and rate of phosphate.

Soil	Phosphate material	Available soil phosphorus in lbs. P_2O_5 per acre* — Lbs. P_2O_5 applied per acre: 0	50	200
Mojave	No phosphorus	18	—	—
	Rhenania-type phosphate	—	28	84
	Concentrated superphosphate	—	31	81
Berthoud	No phosphorus	28	—	—
	Rhenania-type phosphate	—	40	103
	Concentrated superphosphate	—	53	97
Pryor	No phosphorus	13	—	—
	Rhenania-type phosphate	—	22	62
	Concentrated superphosphate	—	22	75
Tripp	No phosphorus	18	—	—
	Rhenania-type phosphate	—	26	104
	Concentrated superphosphate	—	33	92
Millville	No phosphorus	28	—	—
	Rhenania-type phosphate	—	31	81
	Concentrated superphosphate	—	37	92
Sagemoor	No phosphorus	9	—	—
	Rhenania-type phosphate	—	17	93
	Concentrated superphosphate	—	17	81

* Determined as P_2O_5 soluble in 0.5 *M* $NaHCO_3$ of pH 8.5. See (6) in literature citations.

Studies by Brenes[7] have shown that Rhenania-type phosphate decomposes in aqueous media below pH 9.0 or 9.5 to form a very fine white precipitate. X-ray examination revealed that the crystalline material had an apatite-like lattice. Very little water-soluble phosphorus was present. In the soil, the end product of the reaction might be either a discrete phosphate precipitate or a phosphate on the surfaces of the soil particles. In either case, measurements have shown that the reaction may produce as much surface phosphate as that resulting from an equivalent P_2O_5 application from concentrated superphosphate (7). The rate of the reaction should be faster, the finer the particle size of the fertilizer and the greater the mixing of the fertilizer with the soil.

Granulation Studies

The yield of Colsess barley as oven-dry matter and total phosphorus uptake as influenced by different granule sizes of Rhenania-type phosphate are summarized in table 4. All the granulated materials, except −90+180-mesh, produced yields of dry matter significantly lower than those obtained from the finely ground product, −180-mesh. The yields produced by the different degrees of hardness within a granule size did not differ significantly and were averaged to obtain the means of the two granule sizes involved for −4+16

[7] Brenes, E. J. The properties and nature of Rhenania-type phosphates and their availability in calcareous soils. M. S. Thesis, Colorado A and M College. 1954.

Table 4.—Oven-dry weight of barley and phosphorus uptake by plants as affected by granule size of Rhenania-type phosphate. Fort Collins loam.

Phosphate material*	Granule size (mesh)	Dry weight yield gm./4 pots	P uptake mgm. P/4 pots	Relative efficiency	
				Dry weight	P uptake
No phosphorus	———	11.54**	12.03**	—	—
Rhenania-type phosphate, fine	−180	17.48	20.05	100	100
Rhenania-type phosphate, granulated	−90+180	16.59	18.29	85	78
Rhenania-type phosphate, granulated†	−16+50	13.71**	15.25**	37	41
Rhenania-type phosphate, granulated†	−4+16	12.81**	13.81**	21	22
L.S.D. 0.05	———	1.55	1.90		
L.S.D. 0.01	———	2.08	2.57		

* All materials applied at a rate of 60 pounds P_2O_5/2,000,000 pounds soil.
** Significantly lower at 1% level than yield of −180-mesh.
† Values shown are averages of soft, medium, and hard granules.

and −16+50-mesh. The effect of the granulated materials on the phosphorus uptake by the plants was in the same order as their effect on dry matter production.

The relative efficiencies of the various granule sizes shown in table 4 were determined on the basis of the increases obtained in dry matter and total phosphorus uptake above the no-phosphorus treatment using the values for the fine material as 100%.

The oven-dry weights of Dakota Kursk millet as affected by the various granule sizes are tabulated in table 5. The Terry sandy clay loam was very deficient in available phosphorus and all the treatments resulted in marked yield increases above the no-phosphorus treatment. The yields obtained from all the granule sizes with the exception of −60+180-mesh were significantly lower than the yield obtained from the fine product. Again, as in the barley experiment, the smaller the granule size the larger was the increase obtained in yield. The relative efficiencies for the different sizes were calculated in the same manner used for the barley experiment.

In general, as shown by crop yield and phosphorus uptake, the granulated materials were less available than the finely ground product with availability decreasing as the granule diameter increased. These results are in agreement with findings of Crowther, *et al.* (3), which showed that the effectiveness of a high-soda silicophosphate (a Rhenania-type phosphate) improved with decreasing particle size until a fineness of 60-mesh was reached.

The relative external surface areas exposed by the same weight of the different granule sizes were calculated for each

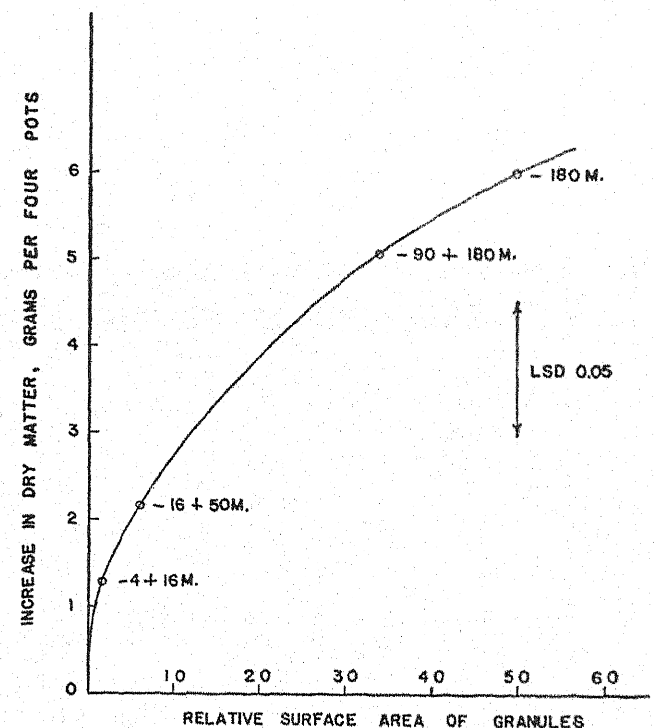

FIG. 1.—Relationship between external surface of Rhenania-type phosphate granules and yield response of barley. Fort Collins loam.

Table 5.—Oven-dry weight of millet as influenced by granule size of Rhenania-type phosphate. Terry sandy clay loam.

Phosphate material*	Granule size (mesh)	Dry weight yield gm/4 pots	Relative efficiency
Rhenania-type phosphate, fine	−180	18.70	100
Rhenania-type phosphate, granulated	−60+180	18.05	96
Rhenania-type phosphate, granulated	−20+180	14.00*	69
Rhenania-type phosphate, granulated	−20+160	14.25*	70
Rhenania-type phosphate, granulated	−9+20	8.22*	30
Rhenania-type phosphate, granulated	−5+20	7.50*	25
Rhenania-type phosphate, granulated	−5+9	6.32*	18
Rhenania-type phosphate, granulated	+5	5.21*	10
No phosphorus	———	3.69	—
L.S.D. 0.05		2.64	
L.S.D. 0.01		3.52	

* Significantly lower than yield of minus-180-mesh at 1% level.
† All materials applied at a rate of 80 pounds P_2O_5 per 2,000,000 pounds soil.

experiment from the mean areas of the granules, assuming that the granules were spherical and that there was an even weight distribution of sizes between the upper and lower limits of the various separates. The values thus obtained were plotted against the corresponding increases in oven-dry weight; the resulting graphs are shown in figures 1 and 2. The graphs indicate that the availability of phosphorus in the granulated Rhenania-type phosphates increased as the relative external surface area of the granulated material increased and that the rate of increase in availability steadily decreased with increasing surface area.

Neither the citrate-soluble P_2O_5 content nor a measurement of external surface area of the original unslaked separates could be ascertained by methods at hand because the granules disintegrated during the determinations, resulting in apparent values essentially equal to the one for the finely ground product. Thus, the application of the granulated phosphate in "equivalent" citrate-soluble P_2O_5 quantities does not necessarily mean that equivalent results will be obtained.

SUMMARY AND CONCLUSIONS

The comparative availabilities of a finely ground Rhenania-type phosphate and concentrated superphosphate in six calcareous western soils were studied in a greenhouse experiment with millet as the test crop. Using dry matter production, total phosphorus uptake, and measurements of available soil phosphorus as criteria, the availability of the Rhenania-type phosphate was found equal to that of concentrated superphosphate.

The effect of granulation upon the effectiveness of Rhenania-type phosphates was also studied. It was found that granulation decreased their availability in calcareous soils.

From the results obtained in this investigation, it was suggested that a Rhenania-type phosphate becomes available largely through the formation of an end product possessing an extensive phosphate surface. Within limits, the finer the fertilizer product, and the more thorough the mixing with the soil, the greater will be the surface phosphate and the available soil phosphorus.

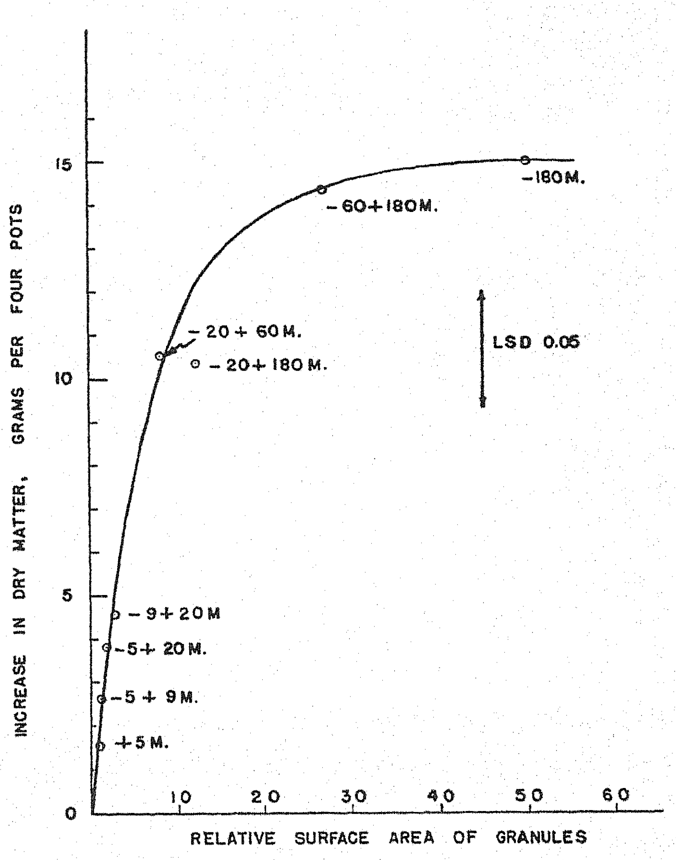

FIG. 2.—Relationship between external surface of Rhenania-type phosphate granules and yield response of millet. Terry sandy clay loam.

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The Effect of Clipping and Grazing on the Subsequent Growth of Winter Oats[1]

Norman Justus and R. L. Thurman[2]

APPROXIMATELY 35% of the average annual oat acreage in Arkansas is harvested for hay and silage. A question as to the importance of plant height and related responses in small grain for hay was suggested by the work of Cutler, *et al.*[3] and Washko.[4] Cutler reported that delayed clipping of wheat reduced plant height subsequently in experiments in Indiana. He also reported that the reduction in plant height was due to the reduction in length of the lower internodes, and the reduction in plant height combined with the shortness of the lower internodes is closely related to lodging resistance. The maturity of the wheat crop was delayed from no days to 5 days depending upon the date and number of clippings. Washko[4] found that grazing reduced plant height and tillering and postponed ripening 4 to 8 days in oats, rye, barley and wheat in experiments in Tennessee.

MATERIALS AND METHODS

Four experiments involving Arkin and Arlington oats were sown Sept. 15, 1953 in a split plot design in four replications at the Main Experiment Station, Fayetteville, Ark. Experiment A received clipped and unclipped treatments. The clipping was accomplished with a lawn mower with the cutter bar set 2½ inches from the ground level. The first clipping was made Oct. 27 and regrowth clippings were made Nov. 19, Dec. 10, Feb. 2 and Feb. 26. Clippings were made when the plots showed sufficient growth for grazing.

Experiment B was sown as a duplicate of Experiment A and was grazed with dairy animals on approximately the same dates when Experiment A plots were clipped. The animals remained in the plots until they had removed about all of the upper leaf forage. The dairy animals grazed the plants closer than they were clipped in Experiment A.

Experiment C was sown at a 1-, 3-, 4- and 5-bushel rate per acre. Experiment D involved 1¾ and 2½ bushel rates per acre in each of 7-and 14-inch row spacings. The clipping treatments of the two experiments were the same as for Experiment A.

The hay was harvested, leaving a stubble about 4 inches high, as the maturity of the plants reached the soft dough stage. The weights were recorded on an air-dry basis which contained approximately 14% moisture. Plant height was measured just prior to harvest.

The leaves and heads were removed from the harvested hay samples. The remainder of the sample is referred to as stripped stems, and the percent stripped stems of the harvested hay sample was determined on a weight basis.

Table 1.—Average oat hay yields, plant height and percent stems of two varieties at four rates of sowing and two clipping treatments.

Rates of sowing in bushels per acre	Tons of air-dry hay per acre		Plant height in inches	Percent stems
	Unclipped	clipped		
1	3.7	3.0	31.3	44.2
3	3.7	3.1	34.3	46.3
4	4.5	3.4	34.4	43.0
5	4.2	2.8	36.3	45.4
Average	4.0	3.1	34.0	44.7
L.S.D. 5% level	1.1		2.8	—
L.S.D. 1% level	1.5		3.8	—

RESULTS AND DISCUSSION

The unclipped plots produced significantly greater air-dry hay yields per acre than did the clipped plots, at the 1% level, in experiment A. There was no significant difference in the plant height of the clipped and unclipped plots. It was not possible to distinguish between the clipped and unclipped plots from plant height alone.

The grazed plots yielded slightly less air-dry hay per acre than did the clipped plots. Plants in the grazed plots were shorter than the plants in the clipped plots which was probably due to the fact that the dairy animals tended to remove a greater percentage of the top growth than was removed by clipping. The grazed plots could not be compared with the unclipped plots statistically.

Maturity was delayed from 3 to 5 days following clipping, and 4 to 8 days following grazing. The destruction of growth of buds by winterkill or other factors could have resulted in differences in hay yields and plant height. The clipping of regrowth which required the advancement of new bud growth probably caused the delayed maturity. If spring clipping is delayed until the early stems are developed, they may be destroyed or injured or the reserve food used, resulting in a reduction in the number of stems to produce hay or mature grain.

The 1-, 3-, 4- and 5-bushel rates of sowing per acre produced average yields of 3.35, 3.40, 3.95 and 3.50 tons of air-dry hay per acre and plant heights of 31.3, 34.3, 34.4 and 36.3 inches, respectively (table 1). The hay yields did not differ significantly but the plant height of the one bushel rate of sowing was significantly lower than the other rates. The rates of sowing had little effect on hay yields despite taller growth by the higher rates. The unclipped plots produced significantly higher yields than the clipped plots.

Mean yields of air-dry hay per acre from the 7- and 14-inch row spacings were 4.1 and 3.0 tons, respectively, which did not differ significantly. The mean plant heights in the 7- and 14-inch row spacings were 36.1 and 30.8 inches, respectively. The 7-inch row spacing produced significantly taller plants than did the 14-inch spacing. Plant height increased directly with increased sowing rates and inversely with increased row spacing.

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[1] Research paper No. 1135 Journal Series, University of Arkansas, Fayetteville, Ark. Published with permission of the Director of the Arkansas Agr. Exp. Sta. Part of a thesis submitted to the University Graduate Council by the senior author in partial fulfillment of the requirements of the M.S. degree. Rec. for publication Sept. 1, 1954.

[2] Graduate Student and Assistant Professor, respectively.

[3] Cutler, G. H., Dioisio, P. S., and Mulvey, R. R. The effects of clipping to stimulate pasturing winter wheat on the growth, and quality of the crop. Jour. Amer. Soc. Agron. 41:169–173. 1949.

[4] Washko, J. B. The effects of grazing winter small grain. Jour. Amer. Soc. Agron. 39:659–666. 1947.

Obviously, the stems of the plants in the 1-bushel rate of sowing and the 14-inch row spacing (the significantly lower plants) were greater in diameter than in the 3-, 4- and 5-bushel rate of sowing and the 7-inch spaced rows, suggesting an increase in the proportion of stripped stems of the hay produced.

The percent stripped stems of the 1-, 3-, 4- and 5-bushel rates of sowing was 44.2, 46.3, 43.0 and 45.4, respectively, and did not differ significantly. The 7- and 14-inch row spacings produced about the same variation in percent stripped stems as was found in the rates of sowing experiment. Percent stripped stems for the clipped plots was higher than for the unclipped plots in the rates of sowing experiment and lower in the row spacings and did not indicate a distinct pattern. The variation among replications was greater than between treatments.

A composite sample of the stripped stems from the four replications of the 1- and 3-bushel rates of sowing was made. The lower internodes of the stripped stems of the 1-bushel rate of sowing averaged 10.6 cm. in length and 12.9 cm. for the 3-bushel rate of sowing. Similar samples from the 7- and 14-inch row spacings gave almost identical measurements as the 3- and 1-bushel sowing rates, respectively. Plants with short internodes would possess approximately the same number of internodes as taller plants with longer internodes and consequently the same number of leaves.

According to Audus,[5] light either destroys or causes a transfer of auxin in plants. The effect of the rate of sowing and spacing on stem and internodal length was probably caused by the auxin level in the plants. The increased amount of light reaching the leaves of the crown branches of the plants in the 1-bushel rate of sowing and the 14-inch row spacing reduced the auxin content of the plants, resulting in shorter lower plants internodes. The plants in the 3-, 4- and 5-bushel rate of seeding and 7-inch spaced rows produced a greater shading effect of the leaves of the crown branches of the plants which allowed a build-up of auxin, resulting in longer internodes.

SUMMARY AND CONCLUSIONS

Experiments were conducted to determine the effect of clipping and grazing on the subsequent growth of winter oats. The unclipped plots produced significantly greater air-dry hay yields per acre than did the clipped plots. Plant height increased directly with increased sowing rates and inversely with increased row spacing. The significantly lower plants possessed shorter lower internodes. Maturity was delayed from 3 to 5 days following clipping and 4 to 8 days following grazing. The percent stripped stems did not follow a distinct pattern.

[5] Audus, L. J. Plant Growth Substances. Interscience Publishers, Inc. N. Y. pp. 48. 1954.

The Effect of Soil Treatments on the Tannin Content of Lespedeza Sericea[1]

Clarence M. Wilson[2]

LESPEDEZA sericea *(L. cuneata)* is now being grown on more than one-half million acres in Alabama. This indicates that sericea holds an important place in the forage crop program of that state.

One of the factors favoring sericea production is its ability to furnish grazing under summer conditions so adverse that most other forage crops cease growth. It is also well adapted to soils of low fertility, and often produces satisfactory yields for several seasons without lime or fertilizer treatments. One of the most unfavorable characteristics of the crop is its low palatability. This has generally been attributed to the relatively high content of tannins or tannic acid (3, 10). The tannin content of sericea leaves is generally 6 to 8% as compared to less than 2% for alfalfa at the hay stage. Tannin contents up to 18% have been reported for sericea leaves where plants were at advanced stages of maturity (2).

Observations by experiment station personnel and farmers have indicated that cattle grazed sericea more readily where lime and/or fertilizers had been applied even where yield responses to such treatments were not apparent. Most reports of this nature have stressed the beneficial effects of lime and in some cases potash.

If it is assumed that tannin affects palatability, and if lime and fertilizers cause the crop to be grazed more readily, one is led to speculate as to whether there is a soil fertility-tannin relationship. Results reported from the Georgia Experiment Station (4) indicated that sericea fertilized with a complete fertilizer and lime contained less tannin than that receiving no fertilizer. Work was started in 1950 to study the effect of soil treatments on the tannin content of sericea. Five field fertility experiments already in progress on five different soil types were utilized in this study. In addition, a greenhouse experiment was set up with a wider range of fertilizer treatments than was present in the field experiments.

[1] Contribution from the Department of Agronomy and Soils, Alabama Agr. Exp. Sta. of the Alabama Polytechnic Institute, Auburn, Ala. Approved for release by the Director. Received for publication Sept. 17, 1954.

[2] Associate Soil Chemist.

MATERIALS AND METHODS

The five field experiments were located on Kalmia, Boswell and Greenville fine sandy loams, Appling sandy loam, and Decatur clay loam. Soils utilized in the field experiments were low in fertility and typical of soils used for sericea production in the respective soil areas. The experimental design employed was a randomized block with three replications. Treatments included phosphorus rates of 50, 100, and 150 pounds of P_2O_5 per acre; potash rates of 60, 120, and 240 pounds of K_2O per acre; and

lime rates of none and 1 ton of dolomitic limestone per acre. All treatments except lime were applied annually. Each plot was 1/400 acre in size. Sericea was seeded on all plots in the spring of 1947. The first samples for tannin analysis were taken in 1950.

A greenhouse fertility experiment with sericea was also started in the spring of 1950. A Norfolk loamy sand of very low fertility was placed in 2-gallon pots. The experimental design was the same as for the field experiments except that four replications were used. Treatments included rates of phosphorus of 0, 60, 120, and 180 pounds of P_2O_5 per acre; potash rates of 0, 60, 120, and 240 pounds of K_2O per acre; lime rates of 0, 1 ton, 2 tons, and 4 tons per acre; and nitrogen rates of 0 and 60 pounds of N per acre. All treatments except lime were applied annually. Sericea was planted in March 1950. Because of an infestation of scale insects during the fall of 1950, all pots had to be reseeded in the spring of 1951. In subsequent years these insects were controlled by the use of parathion. Scale insects are not a problem on sericea grown under field conditions.

Plant samples were taken for tannin analysis when the plants were 12 to 15 inches high (recommended stage to cut for hay). Since other workers (2, 6) had shown that the tannin content of sericea increased with advancing maturity, care was taken to get all samples at as nearly the same stage of maturity as possible. Early in the study, it was found that the occurrence of mold in samples or drying at high temperatures apparently caused a breakdown in tannin so that the results of analysis were low. Therefore, it was necessary to dry samples soon after cutting, holding the temperature at approximately 50° C. For the first cutting on which data are reported, the sample consisted of stems and leaves. Based on reports (2) that the tannin content of sericea stems is low and quite constant as compared to that of the leaves, it was concluded that leaf analysis would offer a better measure of any variations that might occur due to treatments. Thus, leaves were separated from stems and only the leaves were analyzed after the first samplings of both field and greenhouse experiments. At the time samples were weighed for analysis, samples were also taken for moisture determinations. Moisture samples were dried at 90° C, and the percentage of tannin was calculated on the basis of samples dried at that temperature.

Tannin was extracted from the plant material by refluxing 1 gm. of finely-ground (40-mesh) material with 250 ml. of distilled water for 1 hour. Determinations were then made by the procedure described by Rosenblatt and Peluso (5). These authors have shown good agreement between this method and the A.O.A.C. volumetric method (1) for determining the tannin content of wine and whiskey. Valaer (9), reporting on the same method, stated that the tannin in wine was generally considered to be exclusively of catechol type. Clark, Frey, and Hyland (2) stated that tannin in sericea belonged to the catechol class, as shown by the fact that it gives an olive-green color with iron-alum solution and a precipitate with bromine water, and it is completely precipitated by formaldehyde in the presence of hydrochloric acid.

Rosenblatt and Peluso (5) have further pointed out that many methods in use measure constituents besides tannin, whereas methods based on the use of phosphotungstic-phosphomolybdic compounds (Folin-Dennis reagent in this case) are specific for, and give a blue color only in the presence of oxy-phenyl groups, such as are present in tannins.

RESULTS AND DISCUSSION

Field experiments.—The tannin content of sericea grown on five soil types with various fertilizer and lime treatments is shown in tables 1 and 2. A significant difference in tannin content due to soil treatment occurred in only one case during samplings over a 2-year period. In that one instance, the sericea receiving 150 pounds of P_2O_5 per acre was significantly lower than that of the 50-pound rate. This occurred in the first 1950 cutting on the Boswell soil (table 1). As mentioned earlier, plant samples from the first cutting in 1950 included both stems and leaves. This accounts for the fact that tannin analyses of the first cutting were generally lower than those of subsequent samplings.

It should be pointed out that yield records for all locations during 1950 and 1951 did not show any response in plant growth above the first increments of phosphorus and potash. Neither was there any response obtained from lime, although the original soil pH was 5.3 for the Kalmia and Appling soils, 5.5 for Greenville and Boswell soils, and 5.7 for the Decatur soil.

Greenhouse experiment.—The tannin content of sericea grown on Norfolk soil in the greenhouse is given in table 3. Significant differences occurred only for the second cutting in 1951 and for the first and second cuttings in 1952. The major difference appeared in the first 1952 cutting between the 0- and 60-pound rates of K_2O (table 3). The tannin content of sericea from the no-potash treatment was significantly higher than that of samples from pots where potash had been added. It is believed that this difference can best be explained on the basis of the yield data given in table 4. During the first 2 years of cropping, the soil furnished sufficient potash for near maximum growth and plants appeared normal. By 1952 the plants on the no-potash pots were severely stunted. Plant leaves showed severe deficiency symptoms, and some shedding of leaves occurred. Thus, the high

Table 1.—Percentage of tannin in sericea as affected by soil treatment on five soil types—1950.

Soil treatment* Pounds per acre	First cutting†					Second cutting				
	Kalmia	Greenville	Boswell	Appling	Decatur	Kalmia	Greenville	Boswell	Appling	Decatur
					Effect of phosphorus					
50 lb. P_2O_5	3.50	5.18	5.41	5.25	3.89	8.22	6.96	6.00	6.53	7.15
100 lb. P_2O_5	4.11	5.09	5.30	5.49	4.40	8.52	6.98	6.66	6.79	7.14
150 lb. P_2O_5	4.73	4.58	5.09	5.16	3.86	8.26	6.74	7.15	6.59	6.60
					Effect of potash					
60 lb. K_2O	4.18	5.13	5.07	5.73	4.18	8.51	6.70	4.44	6.67	7.17
120 lb. K_2O	4.11	5.09	5.30	5.49	4.40	8.52	6.98	6.66	6.79	7.14
240 lb. K_2O	4.15	4.97	5.47	5.50	3.87	8.36	7.28	6.60	6.87	6.98
					Effect of lime					
No lime	3.15	4.98	5.43	5.91	4.60	8.61	6.91	7.67	7.02	7.06
2000 lb. lime	4.11	5.09	5.30	5.49	4.40	8.52	6.98	6.66	6.79	7.14
L.S.D. (0.05)	N.S.	N.S.	0.25	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Base treatment was 100 lb. P_2O_5, 120 lb. K_2O, and 2,000 lb. lime per acre, applied as 18% superphosphate, 60% muriate of potash, and dolomitic limestone, respectively. When one element was varied, the others were applied at the same base rate.

† Samples from the first cutting consisted of leaves and stems. All subsequent samples included leaves only.

Table 2.—Percentage of tannin in sericea as affected by soil treatment on five soil types—1951.

Soil treatment* Pounds per acre	First cutting					Second cutting				
	Kalmia	Greenville	Boswell	Appling	Decatur	Kalmia	Greenville	Boswell	Appling	Decatur
					Effect of phosphorus					
50 lb. P_2O_5	7.52	5.44	7.21	6.90	7.21	7.66	7.35	10.32	8.41	7.48
100 lb. P_2O_5	7.17	6.30	6.81	6.54	6.95	7.35	7.52	9.55	7.99	7.73
150 lb. P_2O_5	7.34	6.14	6.98	7.16	7.12	6.68	7.73	9.47	8.37	7.85
					Effect of potash					
60 lb. K_2O	7.58	6.66	6.79	7.44	7.32	7.03	7.35	8.73	8.35	7.22
120 lb. K_2O	7.17	6.30	6.81	6.54	6.95	7.35	7.52	9.55	7.99	7.73
240 lb. K_2O	7.64	6.12	7.17	6.99	7.58	7.12	7.61	9.92	8.24	7.46
					Effect of lime					
No lime	7.27	6.97	7.74	7.97	7.10	7.33	8.18	8.93	8.50	7.54
2000 lb. lime	7.17	6.30	6.81	6.54	6.95	7.35	7.52	9.55	7.99	7.73
L.S.D. (0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Base treatment was 100 lb. P_2O_5, 120 lb. K_2O, and 2,000 lb. lime per acre, applied as 18% superphosphate, 60% muriate of potash, and dolomitic limestone, respectively. When one element was varied, the others were applied at the same base rate.

Table 3.—Percentage tannin in sericea as affected by soil treatments on Norfolk loamy sand (Greenhouse).

Soil treatment* Pounds per acre	1950		1951			1952		
	First cutting†	Second cutting	First cutting	Second cutting	Third cutting	First cutting	Second cutting	Third cutting
				Effect of phosphorus				
No P_2O_5	4.87	5.89	7.69	7.68	7.26	8.25	7.73	5.67
60 lb. P_2O_5	4.87	5.90	7.52	7.37	7.09	7.53	6.58	5.44
120 lb. P_2O_5	5.22	6.04	7.65	6.26	6.59	7.33	7.23	5.50
180 lb. P_2O_5	5.07	6.15	6.94	6.10	6.18	6.98	6.68	4.88
				Effect of potash				
No K_2O	5.24	6.47	7.54	6.68	7.01	10.25	8.98	5.43
60 lb. K_2O	5.11	6.18	7.74	5.86	6.31	7.24	7.53	5.56
120 lb. K_2O	5.07	6.15	6.94	6.10	6.18	6.98	6.68	4.88
240 lb. K_2O	5.27	6.33	6.55	7.32	6.28	6.87	6.54	4.86
				Effect of lime				
No lime	4.82	5.44	7.08	6.41	6.30	7.07	6.92	5.16
2,000 lb. lime	5.07	6.15	6.94	6.10	6.18	6.98	6.68	4.88
4,000 lb. lime	4.80	5.68	7.60	6.39	6.30	6.87	6.80	4.94
8,000 lb. lime	4.84	6.00	7.49	6.55	6.63	6.66	6.75	5.15
				Effect of nitrogen				
No N	5.07	6.15	6.94	6.10	6.18	6.98	6.68	4.88
60 lb. N	4.66	5.92	6.66	7.54	6.76	6.99	6.50	5.04
L.S.D. (0.05)	N.S.	N.S.	N.S.	0.66	N.S.	1.22	0.78	N.S.

* Base treatment was 100 lb. P_2O_5, 120 lb. K_2O, and 2,000 lb. lime per acre, applied as 18% superphosphate, 60% muriate of potash, and dolomitic limestone, respectively. When one element was varied, the others were applied at the same base rate.
† Samples from the first cutting in 1950 consisted of leaves and stems. All subsequent samples included leaves only.

tannin content seemed to be associated with the stunted, unthrifty condition of the plants.

It will also be noted that the 1951 yield from the no-phosphorus treatment was very low (table 4). As mentioned earlier, sericea was reseeded on all pots in 1951. Plants on the no-phosphorus treatment showed very poor growth at the first cutting in 1951, but growth was almost as good as that of the 60-pound rate of P_2O_5 at the second and third cuttings. Although growth was slow on the no-phosphorus treatment in 1951 causing low total yield, plants maintained a normal color and did not show marked deficiency symptoms as was true of those on the no-potash treatment. The tannin content of the first cutting from the no-phosphorus treatment was the same as that of samplings from the 120-pound rate of P_2O_5 (table 3). Yields without phosphorus were about the same in 1952 as for 1950 (table 4). Thus, after the root system was developed on the new seeding in 1951, sericea was apparently able to obtain considerable phosphorus from a soil very low in available P_2O_5. Soil analysis at the end of the 1952 growing season showed 31 pounds of dilute acid-soluble P_2O_5 per acre where phosphorus had not been added as compared to 80 pounds per acre for the 60-pound rate of P_2O_5.

Throughout the greenhouse experiments, no significant difference in tannin content was indicated due to lime (table 3). The addition of nitrogen caused a significant increase

in tannin in one cutting out of eight. It is also interesting to note that there was less growth response to the various rates of lime and nitrogen than was true for phosphorus and potash. The pH of the original soil was 6.2.

From the results of 2 years' study on 5 field experiments and 3 years' study on a greenhouse experiment, it appears that soil treatments of fertilizer and lime have very little effect on the tannin or tannic acid content of sericea, except in cases where nutrients are limited to the extent that extreme deficiency symptoms occur in the plants. In such cases the tannin content tends to be increased. It is conceivable that any other growth factor, such as moisture, might be limited to the point where the same effect would be produced.

Other factors, such as stage of growth (2, 6) and heredity (7) probably have a greater effect on the tannin content of sericea than do soil treatments. Stitt, *et al.* (8) also reported that the tannin content of sericea varied with soil types, but the same report pointed out that such climatic factors as moisture, temperature, and light intensity may also influence the tannin present. From tables 1 and 2, it will be noted that there appear to be differences between soil types. However, since the experimental areas were rather widely separated geographically and subject to varying climatic factors, it is doubtful that any apparent differences could definitely be attributed to soil differences. For that reason the data reported in this paper have not been analyzed statistically for differences between soil types. It is interesting that the results obtained from the Kalmia and Decatur soils are very similar for most cuttings. The Kalmia soil located at Brewton, Ala., is a fine sandy loam, while the Decatur soil at Alexandria, Ala., is a heavy clay loam. Since these soils differ greatly in physical and chemical properties, one is led to suspect that other factors exerted more influence on tannin content than did soil types.

SUMMARY

Five field experiments representing five soil types and a greenhouse experiment on one soil type were conducted to determine the effect of rates of fertilizers and lime on the tannin content of sericea.

The only major difference measured was a decrease in tannin in plants getting K_2O at the rate of 60 pounds per acre as compared to those without K_2O. This difference was obtained on a Norfolk loamy sand in greenhouse pots, and it occurred in the third crop year after plants were showing extreme deficiency symptoms and yields were severely reduced on the no-potash treatment.

It is concluded that mineral fertilizers and lime have little if any effect on the tannin content of sericea, except in cases where nutrients are limited to the point that plant growth is severely inhibited. It appears that where a nutrient deficiency does limit growth of sericea, the tannin content may be significantly increased.

Table 4.—Annual yields of sericea from greenhouse experiment.

Soil treatment, pounds per acre	Grams dry matter per pot*		
	1950	1951	1952
	Effect of phosphorus		
No P_2O_5	18.8	8.8	16.2
60 lb. P_2O_5	20.7	14.0	19.6
120 lb. P_2O_5	21.5	22.1	26.0
180 lb. P_2O_5	24.0	19.8	27.1
	Effect of potash		
No K_2O	22.1	17.4	5.8
60 lb. K_2O	22.0	23.2	25.5
120 lb. K_2O	24.0	19.8	27.1
240 lb. K_2O	21.4	12.7	19.1
	Effect of lime		
No lime	19.8	19.8	24.4
2000 lb. lime	24.0	19.8	27.1
4000 lb. lime	22.2	19.6	18.1
8000 lb. lime	20.9	18.1	26.5
	Effect of nitrogen		
No N	24.0	19.8	27.1
60 lb. N	24.2	18.0	26.9
L.S.D. (0.05)	N.S.	4.6	8.2

* All yields are total for three cuttings made each year.

Although there appeared to be differences in the tannin content of sericea from different soil types in the field experiments, it is doubtful that this can be attributed to soil differences since climatic factors such as moisture, temperature, and light intensity could not be controlled.

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Opportunities in College Teaching in the Field of Agronomy[1]

Louis M. Thompson[2]

THERE are approximately 200 staff members who are primarily engaged in teaching agronomy in the land grant colleges and universities in this country. There are many more than this number who do some teaching in addition to research. In the past, it has been possible to recruit teachers in agronomy from among graduate students to take care of replacement needs, yet considerable correspondence takes place between department heads each year before teaching positions are finally filled by competent men who are interested in teaching. For the next 7 years, and perhaps longer, the problem of securing personnel for both replacements and expansion will persist. By 1960 the agronomy teaching load will be increased by about 40 percent.

There are approximately 800 graduate students (not counting full-time staff members taking graduate work) in this country. Less than 10% of these students have indicated an interest in a position that is primarily teaching. This number of men interested in teaching will just about take care of replacement needs as these students complete their graduate work. Interest in teaching must be increased if colleges are to expand their teaching program and fill teaching positions with the most capable men.

The lack of interest in teaching on the part of the graduate students is due largely to greater recognition of research men on a national level. Research men have the opportunity to become known through publishing research papers and by personal appearance in Society meetings. This advantage to a research man is voiced so frequently among graduate students that many potential teachers turn to research for fear of a dead-end road in teaching. There is a general feeling among graduate students that the opportunities in research greatly exceed those in teaching, particularly from the standpoint of income. A survey made during the present fiscal year, (1954) however, shows that teachers are doing better than is generally realized.

Top Salaries Paid to Research Men and Teachers

There is a difference in top salaries paid to research men and teachers, but not so great as frequently expressed. There are 35 departments which have men devoting more than half time to teaching on a 12-month basis. In three of these departments the top salary is paid to a teacher. In six departments, the top salaries are the same for research men and teachers. Twenty-six of the departments are paying higher salaries to their top research men than to their top teachers. The average of the top salaries paid to research men in these 35 departments is $7,602. The average of the top salaries paid to teachers in these same departments is $7,045.

In 15 departments there is no one who devotes more than half-time to teaching. The average of the top salaries in these departments is $7,829.

[1] Journal paper No. J-2708 of the Iowa Agr. Exp. Sta., Ames, Iowa.

The data in this report were obtained by questionnaires which were sent to all Department Heads in the field of Agronomy in the Land Grant Colleges and Universities and to the Office of Education, U. S. Department of Health, Education and Welfare. Rec. for publication March 1, 1954.

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Table 1.—Top salaries paid on a 12-month basis in 55 departments (excluding department heads) and top salaries of research men compared to top salaries of teachers in 35 departments.

Range	Top salaries in 55 departments	Comparison of top salaries in 35 departments	
		Research men	Teachers
11,000–12,000	2	0	1
10,000–11,000	1	0	0
9,000–10,000	5	4	0
8,000– 9,000	13	8	5
7,000– 8,000	18	14	14
6,000– 7,000	11	5	8
5,000– 6,000	5	4	6
4,000– 5,000	0	0	1

Only 5 departments have their top teachers on a 9-month basis. The average of the salaries paid to the top teacher in these departments is $5,836 with a range from $4,500 to $7,500. The average of the top salaries paid to research men (12-month basis, however) in these five departments is $8,208.

Table 1 shows the distribution of top salaries paid to research men and teachers. There were 55 responding departments but only 35 with men teaching more than half time on a 12-month basis.

Three department heads explained that the lower salaries paid to their top teachers than to their top research men are due to difference in age, tenure and academic rank.

The value of research men is greatly influenced by their ability to teach. Most research men do some class-room teaching, and all are called on to speak to groups at one time or another. The most valuable men, and consequently the highest paid men, are those who are good in research and good in teaching.

Opportunities for Instructorships

For those who are interested in teaching as a primary duty, the instructorship offers excellent opportunities. The average salary of the instructor compares favorably with starting salaries of other college graduates The instructor can earn a Ph.D. while on the job. He is credited with full-time experience while doing graduate work, and he has the added advantage of establishing a reputation by the time he receives the Ph.D. degree. During the past 5 years, the highest offers to men graduating with the Ph.D. from Iowa State College have been to young men who served as instructors while earning the degree.

The average of the starting salaries of the instructor on a 9-month basis is $3,543 with a range of $2,200 to $4,500 in 23 departments. Only one department is paying less than $3,000 and five departments are paying more than $4,000 on a nine-month basis. Fourteen departments reported that they employ instructors on a 12-month basis. The average starting salary is $3,937 with a range from $3,000 to $4,900.

The encouraging feature is that college instructorships promise considerable advancement for good men. On a 12-month basis, the average of the salaries of the highest paid

teachers is about 80% higher than the average of the starting salaries paid to instructors.

General Comments

Many department heads recognize the fact that the prestige of their departments is as greatly affected by good teaching as by good research. The student opinion, over a period of years, greatly affects the reputation of a department, particularly at the state level, and the opinion is determined largely by contacts with teachers because undergraduate students have little contact with research. More and more department heads are recognizing the need for good teachers and are willing to bid for them, and pay as much for top teachers as for top research men. This is a good trend.

That teaching is a dead-end road is a serious misconception. It is true that some teachers never attain high academic rank. This is what the pessimist sees, but the optimist calls attention to the large number of college presidents, deans and department heads who distinguished themselves as teachers. These successful men gained by their teaching experience. They maintain that the necessity of getting along with students, the practice in communicating ideas, and the experience in standing before an audience was the best training that a college administrator could ask for.

A Karyological Survey of Several Bromus Species[1]

F. L. Barnett[2]

WITH growing interest in interspecific hybridization as a possible means of improving forage crops, the need for karyological information on wild relatives of cultivated species is becoming increasingly apparent. In any interspecific hybridization program a logical crossing arrangement and a sound karyological analysis of the F_1 require information on chromosome number and meiotic behavior of the parent species. Chromosome morphology of the parent species might also be valuable information. This study, involving species of the sections Bromium, Bromopsis, Ceratochloa, and Eubromus in the genus Bromus, was carried out to facilitate and systematize interspecific hybridization at the U. S. Regional Pasture Research Laboratory.

LITERATURE REVIEW

Chromosome number for species of Bromus has been reported by several workers (2, 3, 6, 9, 11). According to available literature the species constitute a euploid series extending from diploid (2n = 14) to 12-ploid (2n = 84). Stebbins (12) reported even higher complements for certain artificial allopolyploids. Darlington and Janaki-Ammal (1) have summarized reports of chromosome numbers for more than 50 species of Bromus.

The meiotic behaviors of several Bromus species have been investigated (2, 3, 4, 9, 11, 12). With few exceptions the diploid, tetraploid, and hexaploid species have been found to exhibit regular meiosis with complete, or nearly complete, bivalent chromosome pairing. Regular meiotic behavior has also been reported for the octoploid *B. carinatus* and the 12-ploid *B. arizonicus*. On the other hand, the octoploid and decaploid species of Bromopsis have been described as exhibiting frequencies of univalents and multivalents at diakinesis and varying degrees of irregularity in later meiotic stages.

Literature on chromosome morphology of Bromus species is limited. Stebbins and Love (13) reported similar chromosome size and morphology for the Bromopsis diploids: *B. grandis*, *B. laevipes*, and *B. orcuttianus*. The karyotype of *B. carinatus* has been described as possessing seven large and 21 medium-sized pairs of chromosomes (14).

MATERIALS AND METHODS

Plant materials used in the present study are listed in table 1. The so-called *B. erectus* aberrants consisted of four groups of plants which were closely similar to, but not identical with, *B. erectus* Huds. Two of these groups were obtained from Portugal, a third originated in Canada, and the fourth was acquired through the Soil Conservation Service. There was some doubt concerning the taxonomic status of the material listed as *B. intermedius* Guss. It was received as *B. severtzonii (B. sewerzowi?)* and later reclassified as "probably" belonging to *B. intermedius*.

During the fall and winter of 1952–53 all materials were grown in the greenhouse, and root tip and anther collections were obtained from them. The greenhouse temperature was thermostatically controlled at approximately 72° F. during the day and 60° F. at night. Artificial lighting from 1:00 a.m. to 2:00 a.m. provided the equivalent of a long-day photoperiod.

Chromosome counts were made on all species. Determinations were based primarily on root-tip smears, but were substantiated in most cases by examinations of anther material. Anther smears of all materials provided information on:

(1) Nature of chromosome pairing at diakinesis or metaphase I,
(2) Nature and frequency of irregularities at anaphase I.
(3) Frequency of quartet micronuclei.

Both root-tip and anther preparations were examined for conspicuous features of chromosome morphology. It should be emphasized, however, that this phase of the study was not explored in great detail, but tended to be incidental to the investigations on chromosome number and meiotic behavior.

Root-tip smears were prepared according to the Hanson-Oldemeyer (5) technique which involves fixing in acetocarmine and subsequent smearing in the same material. Where interpretation proved exceptionally difficult the root tips were placed in a saturated solution of paradichlorobenzene for 2 to 3 hours before fixation. The purpose of this modification was to shorten the chromosomes and thus facilitate interpretation of the figures (10). Suitable slides were made semi-permanent by sealing with paraffin and gum mastic or with fingernail polish.

To obtain material for meiotic examination, entire panicles (or in some cases parts of panicles), collected at the appropriate stage of maturity, were fixed in a solution of one part glacial acetic acid and three parts absolute alcohol. For prolonged preser-

[1] Contribution No. 136 of the U. S. Regional Pasture Research Laboratory, Field Crops Research Branch, ARS, USDA, State College, Pennsylvania, in cooperation with the twelve Northeastern States. Authorized for publication on Aug. 9, 1954 as paper No. 1893 in the Journal Series of the Pennsylvania Agricultural Experiment Station. This paper is a condensation of a thesis submitted in partial fulfillment of the requirements for the M.S. degree at The Pennsylvania State University. The writer is indebted to Dr. A. A. Hanson, who suggested the problem and provided guidance during the early stages of the work and to Drs. H. L. Carnahan and Helen D. Hill for advice, and critical reading of the manuscript. Dr. J. R. Swallen, Smithsonian Institution kindly assisted in the taxonomic identification of many of the plant materials. Rec. for publication Sept. 20, 1954.

[2] Agent.

vation the material was left in the fixing solution, and placed in a cold room maintained at approximately 0° C. The anthers were subsequently dissected out of the florets, and smeared in acetocarmine according to the McClintock method (7).

EXPERIMENTAL RESULTS

Chromosome complements.—Chromosome numbers, as ascertained from examinations of available plants, are given in the second column of table 1. Observed complements ranged from diploid to 12-ploid. Three of the four groups of *B. erectus* aberrants were found to be decaploids (2n = 70). The fourth, one of the lots obtained from Portugal, proved to be a 12-ploid (2n = 84).

Meiotic behavior.—Observations on the meiotic behavior of the various species are summarized in table 1. All diploid species, i.e. *B. anomalus*, *B. grandis*, *B. japonicus*, *B. laevipes*, *B. orcuttianus*, *B. scoparius*, and *B. tectorum* var. *nudus*, exhibited regular meioses. Their chromosomes paired bivalently, and irregularities at anaphase I and the quartet stage were rare. In the case of *B. japonicus* and *B. scoparius* chromosome pairing was studied at metaphase I rather than diakinesis. The univalents reported for these species occurred in cells which were approaching anaphase I, and appeared to have arisen from normally-dividing bivalents. A slight deviation from the bivalent type of pairing occurred in *B. anomalus* in which a single cell appeared to possess one univalent, five bivalents, and three trivalents.

The tetraploids, *B. ciliatus*, *B. frondosus*, *B. intermedius*, and *B. mollis* were relatively regular in meiotic behavior. Chromosome pairing was almost completely bivalent in these four species. A single pollen mother cell of *B. intermedius* exhibited an apparent quadrivalent, and in *B. frondosus* two cells showed two univalents. The chromosomes of *B. intermedius* and *B. frondosus* possessed considerable stickiness, and were frequently clumped. This clumping tendency, which often resulted in close associations of bivalents, was suggestive of multivalency, and caused difficulty in the interpretation of figures.

The fifth tetraploid, *B. tomentellus*, frequently exhibited quadrivalents at diakinesis. Pairing was predominantly bivalent, but most cells showed at least one quadrivalent. Trivalents and univalents were not observed. The species exhibited little irregularity at anaphase I, and the frequency of quartet micronuclei was rather low.

The hexaploids *B. catharticus* and *B. haenkeanus* were regular throughout meiosis. Chromosome pairing, as observed at diakinesis, was entirely bivalent. Anaphase I irregularities were rare in both species, and no quartet micronuclei were observed. Limited data on the hexaploid *B. valdivianus* indicated complete bivalent chromosome pairing.

The higher polyploids of Bromopsis, i.e. *B. inermis*, *B. pumpellianus*, and the *B. erectus* aberrants, exhibited marked meiotic irregularity. Chromosome clumping and stickiness, together with difficulty consequent to large numbers of chromosomes, made it practically impossible to obtain detailed information on chromosome pairing at diakinesis. The pairing relationships exhibited by *B. inermis*, *B. pumpellianus*, and the 70-chromosome aberrants of *B. erectus*, however, may be described qualitatively as follows:

Table 1.—Chromosome numbers and meiotic behavior.

Section and species	2n	Diakinesis or Metaphase I					Anaphase I			Quartets	
		No. of P.M.C.	Mean No. per P.M.C. of				No. of P.M.C.	Mean No. per P.M.C. of		No. of quartets	Mean No. of micronuclei per quartet
			Univ.	Biv.	Triv.	Quad.		Laggards	Bridges		
Section Bromium											
B. intermedius Guss.	28	22	0	13.91	0	0.05	111	0.23	0.03	200	0.10
B. japonicus Thunb.	14	69	0.23	6.88	0	0	181	0.06	0.04	202*	0.08*
B. mollis L.	28	25	0	14.00	0	0	158	0.18	0.07	142	0.02
B. scoparius L.	14	34	0.53	6.74	0	0	33	0.21	0	8*	0.12*
Section Bromopsis											
B. anomalus Rupr.	14	30	0.03	6.94	0.03	0	116	0.15	0.07	—	—
B. ciliatus L.	28	59	0	14.00	0	0	268	0.09	0.02	200	0.04
B. erectus Huds.	70	—	—	—	—	—	394	0.56	0.01	595	1.18
(aberrants)	84	—	—	—	—	—	70	3.18	0.01	166	1.74
B. frondosus (Shear) Woot. and Standl.	28	80	0.05	13.97	0	0	398	0.10	0.13	500	0.15
B. grandis (Shear) Hitchc.	14	40	0	7.00	0	0	200	0.04	0.01	200	0.02
B. inermis Leyss.	56	—	—	—	—	—	343	0.77	0.03	582	1.01
B. laevipes Shear.	14	40	0	7.00	0	0	200	0.04	0.07	200	0.02
B. orcuttianus Vasey.	14	19	0	7.00	0	0	95	0.05	0.03	100	0.10
B. pumpellianus Scribn.	56	—	—	—	—	—	100	2.67	0.02	100	0.67
B. tomentellus Boiss.	28	40	0	12.15	0	0.92	200	0.06	0	200	0.13
Section Ceratochloa											
B. catharticus Vahl.	42	69	0	21.00	0	0	17	0.12	0	39	0
B. haenkeanus (Presl.) Kunth.	42	19	0	21.00	0	0	20	0.05	0.05	18	0
B. valdivianus	42	4	0	21.00	0	0	—	—	—	—	—
Section Eubromus											
B. tectorum var. *nudus* Klett. and Richt.	14	32	0	7.00	0	0	21	0.05	0.14	88	0.03

* Micronuclei counts were obtained from the microscope rather than the quartet stage. Data have been placed on a quartet basis.

(1) There were fairly high frequencies of univalents and multivalents although more than half of the chromosomes were usually paired as bivalents.

(2) Quadrivalents were the predominant class of multivalents.

(3) Occasional octavalents were the largest configurations observed.

As indicated in table 1, the three species exhibited high frequencies of laggards at anaphase I. These consisted largely of univalents which in many cases were dividing. Numerous quartet micronuclei supported evidence of irregularity at diakinesis and anaphase I.

Inter-plant differences were apparent in *B. inermis* and the *B. erectus* aberrants. Some plants exhibited almost complete bivalent pairing, and were relatively regular in later meiotic stages. Others showed high frequencies of univalents and multivalents at diakinesis, marked irregularity at anaphase I, and high frequencies of quartet micronuclei.

Meiotic preparations of the 12-ploid *B. erectus* aberrant were of particular interest. Diakinesis cells were difficult to find, and the few observed were generally so confusing that interpretation was impossible. A single floret yielded giant diakinesis cells of the type shown in figure 1, H. The chromosomes in these cells were sticky, and tended to clump. There appeared to be both univalents and multivalents although a large proportion of the chromosomes were paired as bivalents. There seemed to be more than 100 chromosomes in these cells although root-tip preparations of the same plant indicated a complement of 84 chromosomes. Figures of anaphase I and the quartet stage were obtained from other florets of the same plant, and showed no marked size deviation from comparable cells of the other *B. erectus* aberrants. Anaphase I cells exhibited extreme irregularity with lagging univalents accounting for most of the abnormality. The frequency of 1.74 micronuclei per quartet was in accord with evidence of irregularity at diakinesis and anaphase I.

Chromosome morphology.—Chromosome satellites were observed in somatic cells of a number of the species. A single pair of satellite-bearing chromosomes was observed in each of the diploids: *B. anomalus*, *B. grandis*, *B. laevipes*, and *B. orcuttianus* and in the tetraploid *B. intermedius*. Two pairs of such chromosomes were observed in somatic cells of *B. frondosus*. Small bodies which resembled satellites but could not be definitely identified as such were observed in somatic cells of *B. tomentellus*, *B. inermis*, and the 84-chromosome aberrant of *B. erectus*. The satellites were generally inconspicuous, being clearly discernible in occasional cells only.

Chromosome-size differences seemed to exist both within and among certain species. Each of the tetraploids, *B. frondosus* and *B. intermedius* appeared to possess a mixture of long

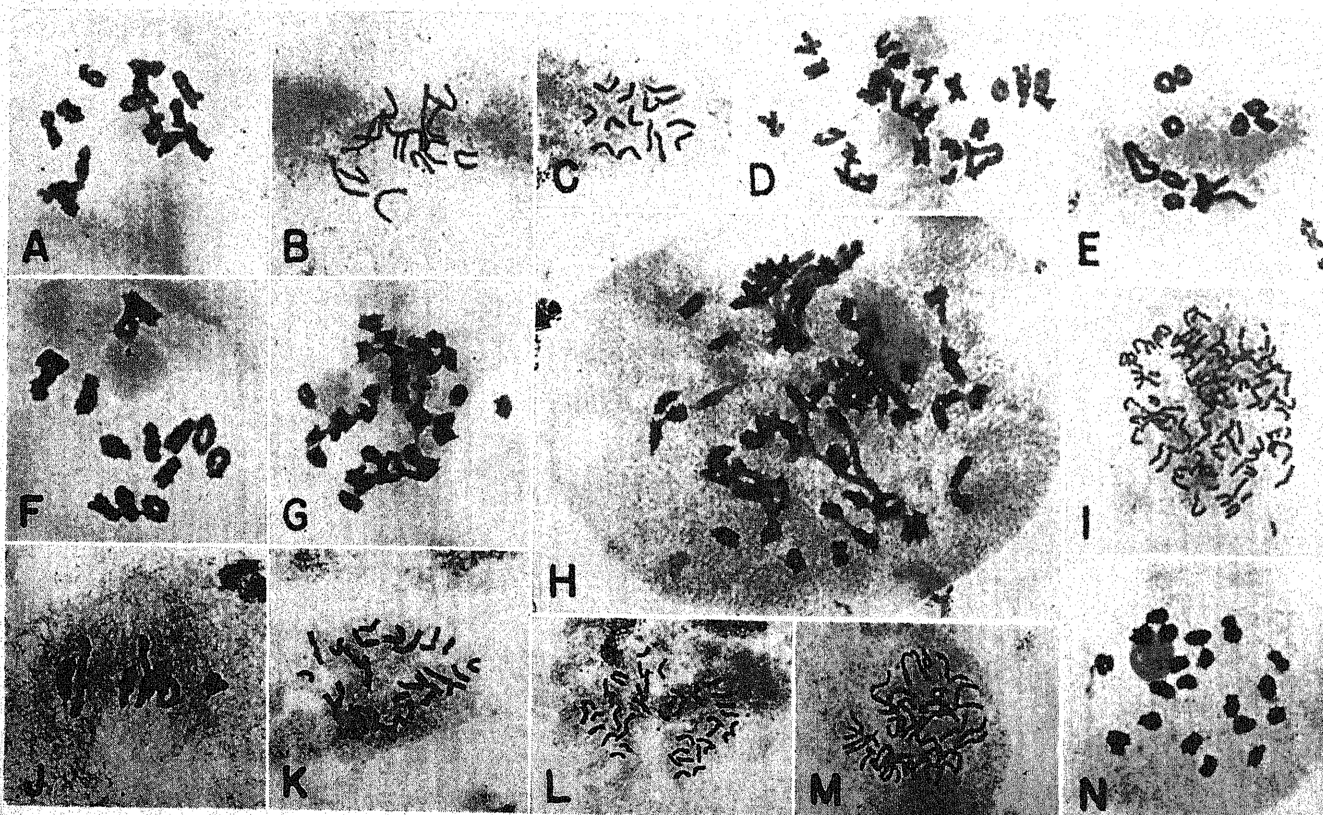

FIG. 1.—Meiotic and mitotic divisions in Bromus species (magnification approximately 700x). (A) Diakinesis of *B. frondosus* showing 14 bivalents; (B and C) Somatic metaphases of *B. grandis* and *B. anomalus*, respectively, showing satellite-bearing chromosomes; (D) Diakinesis of *B. inermis* with univalents and multivalents; (E) Diakinesis of *B. tomentellus* with 12 bivalents and one quadrivalent; (F) Diakinesis of *B. ciliatus* showing 14 bivalents; (G) Diakinesis of 70-chromosome aberrant of *B. erectus* showing multivalent configuration; (H) Giant diakinesis cell of 84-chromosome aberrant of *B. erectus;* (I) Somatic metaphase of 84-chromosome aberrant of *B. erectus* (pre-treated with paradichlorobenzene); (J) Metaphase I of *B. scoparius;* (K) Somatic metaphase of *B. intermedius* showing satellite-bearing chromosomes; (L and M) Somatic metaphases of *B. catharticus* and *B. valdivianus*, respectively; (N) Diakinesis of *B. baenkeanus* with 21 bivalents.

and short chromosomes. Within the section Bromopsis the species *B. grandis*, *B. laevipes*, *B. orcuttianus*, *B. ciliatus*, and *B. frondosus*, seemed to have larger chromosomes than *B. anomalus*, *B. tomentellus*, *B. inermis*, *B. pumpellianus*, and the *B. erectus* aberrants. Root-tip preparations suggested that the chromosomes of *B. valdivianus* were longer than those of *B. catharticus* and *B. haenkeanus*, but anther smears failed to confirm these apparent differences.

DISCUSSION

With a few exceptions the observed chromosome numbers are in agreement with previous reports. *B. intermedius*, reported by Avdulov (1) to possess 14 chromosomes, was found to be a tetraploid with 2n = 28. It should be recalled, however, that there was some doubt concerning the species identity of the material examined in the present study. The complement of 14 chromosomes observed for *B. anomalus* substantiates the findings of Elliot (3), but is at variance with an earlier report of 2n = 28 by Nielsen and Humphrey (11). *B. ciliatus*, observed as 2n = 28, has been reported as possessing 14 (1, 2), 28 (2, 3), and 56 chromosomes (11). The complement of 56 chromosomes observed for *B. inermis* is the number most commonly reported for that species (1, 2, 3, 6) although there are also reports of 28 (4, 8), 42 (1, 11), and 70 (11). The count of 2n = 56 for *B. pumpellianus* is supported by previous findings of Elliot (2, 3), but does not agree with a count of 2n = 42 reported by Stählin (1). The complements of 70 and 84 chromosomes observed for the *B. erectus* aberrants can scarcely be considered as agreeing or disagreeing with previous reports since these materials were not identical with *B. erectus*. *B. erectus* Huds. has been reported as possessing 42 (1), 56 (2), and 70 chromosomes (3). The present report is apparently the first on chromosome numbers for the following species: *B. frondosus* (2n = 28), *B. scoparius* (2n = 14), *B. tomentellus* (2n = 28), *B. tectorum* var. *nudus*[3] (2n = 14), and *B. valdivianus* (2n = 42).

Scarcity of multivalents in tetraploid and hexaploid species is an interesting feature. With the exception of *B. tomentellus* all tetraploids and hexaploids exhibit complete (or nearly complete) bivalent chromosome pairing. According to available literature, *B. tomentellus* is as yet the only Bromus tetraploid described as exhibiting a definite frequency of quadrivalents.

Complete bivalent pairing in a polyploid is generally considered to be indicative of allopolyploid origin. The occurrence of chromosome-length differences in *B. frondosus* and *B. intermedius* is suggestive of allopolyploidy. *B. catharticus* and *B. haenkeanus* have been shown to be allopolyploids (12).

Complete bivalent pairing cannot be taken as conclusive evidence of allopolyploidy nor can the occurrence of quadrivalents be accepted as final proof of autopolyploidy. Chromosome pairing in polyploids is affected by chiasma frequency and chromosome length as well as chromosome homology. Selection toward a bivalent, and hence a more regular, type of meiosis may have occurred in many autopolyploids. On the other hand, heterozygous reciprocal translocations could account for quadrivalents in *B. tomentellus*.

In view of the passing attention given to chromosome morphology, the apparent differences in chromosome size should be considered with reservation. In the absence of actual measurements the magnitude and constancy of these differences are not known. Apparent chromosome size may be influenced by fixation and staining reactions, the position of the chromosome in the cell, and possibly by slight variations in stage of cell division.

[3] The species *B. tectorum* was previously reported as 2n = 14 (1). The variety *nudus*, however, is reported here for the first time.

SUMMARY

A karyological survey of several Bromus species was carried out to facilitate an interspecific hybridization study. Included in the survey were representatives of the sections, Bromium, Bromopsis, Ceratochloa, and Eubromus. Features involved in the study were chromosome numbers, meiotic behavior, and, to a lesser extent, chromosome morphology.

Chromosome complements reported apparently for the first time were: *B. frondosus* (2n = 28), *B. scoparius* (2n = 14), *B. tomentellus* (2n = 28), *B. tectorum* var. *nudus* (2n = 14), and *B. valdivianus* (2n = 42). Aberrant forms of *B. erectus* possessed complements of 70 and 84 chromosomes. A complement of 2n = 56 was observed for *B. inermis*.

With the exception of *B. tomentellus* all diploid, tetraploid, and hexaploid species showed complete (or nearly complete) bivalent chromosome pairing. *B. tomentellus* exhibited a variable frequency of quadrivalents. Octoploid and decaploid species exhibited variable frequencies of univalents and multivalents. Quadrivalents were the predominating class of multivalents in these higher polyploids.

Chromosome stickiness was observed in diakinesis cells of a number of species. This feature was especially notable in the higher polyploids of Bromopsis.

Chromosome satellites were observed in somatic cells of a number of species. Apparent differences in chromosome length, both within and among certain species, were noted.

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Relationship Between Stand and Yield in Alfalfa Variety Comparisons[1]

T. S. Ronningen and A. G. Hess[2]

As NEW varieties of alfalfa are released, critical information on their relative performance over a state or region is desirable within a relatively short time. To accomplish this most satisfactorily, tests are established in as many locations as can be handled efficiently, and careful measurements or observations of important characters are made.

In Maryland, most farmers require an alfalfa variety which will persist and yield satisfactorily over three harvest-years or longer. Replicated variety trials have been established in recent years in various locations in the state from which yield samples have been taken to differentiate among varieties with respect to yield and persistance. In addition, observational notes were taken on other important characters. The number of such locations were limited because of the amounts of labor and time required. Preliminary observations suggested a strong relationship, especially in the third harvest-year, between yield and number of surviving plants per unit of area. The object of this study was to determine the closeness of such a relationship at several locations. If yield and stand counts varied together closely, varietal differences in yield and persistence could be estimated relatively by stand counts. Thus, in addition to data from trials established for actual yield comparisons, information on new alfalfa varieties or advanced strains could be obtained from many more areas of the state in a relatively short time. If such auxiliary plantings were a part of farmers' alfalfa fields, all operations of cutting and removing of hay could be done by the farmer.

Previous workers have reported on the relationship of stand counts or estimates to productivity or persistence of alfalfa. Hanson and Allison[3] found highly significant differences in reduction of stands among a number of alfalfa strains grown in rows in North Carolina. Kramer and Davis[4] found that the number of 6-inch gaps in drill-seeded rows were negatively correlated with yields in the first 2 years from seedings of a regional uniform alfalfa nursery. The relationship was strongest in the first harvest-year. Willard[5] working with alfalfa and sweet clover in Ohio found no significant correlations between stand counts and yields. Older stands were not considered separately from younger stands in this study.

MATERIALS AND METHODS

Alfalfa variety tests were established as pure stands in eastern, northeastern, and central Maryland and with smooth bromegrass in northwestern Maryland in the late summer of 1948. Broadcast seedings were made in 6- by 20-foot plots replicated 4 times in a randomized complete block design. The varieties and strains included were Williamsburg, Buffalo, Kansas Common, Atlantic, Ranger, Grimm, A 225, A 224 and a strain developed and grown at approximately 39° S. Latitude in Argentina. Yields were obtained by harvesting a 3-foot strip from the center of each plot after the ends of the plot had been removed. Dry matter samples were used to correct for differences in moisture content. Botanical estimates, occasionally checked by hand separations, were used in correcting yields to tons of the alfalfa component at 12% moisture per acre.

Stand counts were made in September 1950 following the second harvest-year and again in October 1951. Counts were made within a steel hoop circumscribing an area of 1.4 square feet at 3 separate locations in each plot. Counts were made also in April and July 1951, but those counts, which were intermediate in their correlation with yields, are not included in the data.

EXPERIMENTAL RESULTS

Stand counts made in September 1950 were not correlated significantly with yields of that year as may be noted in table 1. However, correlations of stand counts made in October 1951 with third-year yields were highly significant, for the most part. Whether varietal differences were analyzed

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Table 1.—Correlations of September 1950 stand counts with 1950 yields of 9 alfalfa varieties and October 1951 stand counts with 1951 yields and F values obtained from an analysis of variance of varietal differences based on stand counts and yields separately.

Location	1950	1951		
	r	r	F Values	
			Stand counts	Yields
Eastern Maryland	+0.424	+0.541	N.S.	6.66**
Northeastern Maryland	+0.548	+0.744*	5.75**	10.01**
Central Maryland	+0.611	+0.833**	10.50**	15.18**
Northwestern Maryland	+0.566	+0.901**	6.10**	30.15**

* Exceeds 5% level of significance.
** Exceeds 1% level of significance.

on the basis of yields or stand counts the F values were quite similar at each location.

The closeness of the relationship between stand counts and yields in the third year is illustrated graphically in figure 1 which portrays the varietal averages for the four trials. The relative standing of A 224 was not the same on the basis of yields and stand counts. However, the lower relation of A 224 on the basis of stand counts was closer to relative yield performance of this strain in more recent tests. The more spreading growth habit of plants of A 224 may have been partly responsible for the low relationship of stand and yield of that variety. In these tests, varieties did not differ significantly in first-year yields at any of the locations. Significant differences in yield of the varieties was obtained at all but the eastern Maryland location in 1950. Yield differences were most marked in the third harvest-year.

DISCUSSION AND CONCLUSIONS

The data seem to emphasize the need of carrying on some alfalfa variety tests where yields are measured directly. However, the auxiliary value of stand counts for determining relative performance of alfalfa varieties seems well established for Maryland conditions. On the basis of these results five to ten replicated variety tests on which harvests will not be made have or are being established at widely differing locations in Maryland. These are located in farmers' fields. Observational notes on important characters will be taken from time to time, and stand counts at the end of the third harvest-year will be made to serve as an indirect check on varietal differences in yield and persistence. Replicated variety tests at three to five locations in which harvests are made will be continued. The establishment of such variety tests as a corollary to the standard alfalfa variety testing program will have the following advantages when funds for testing are somewhat limited: *(1)* Test results may be obtained from a greater number and diversity of test locations in a restricted period of time. *(2)* Possible

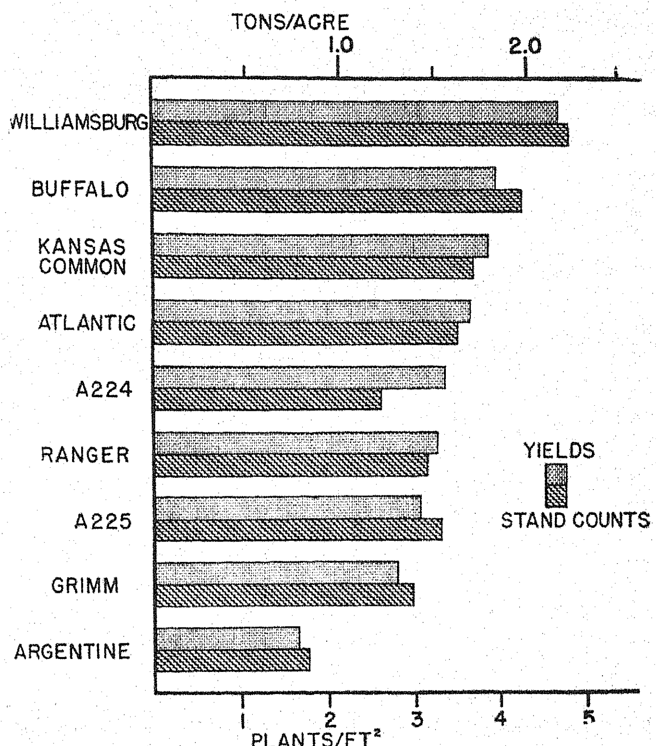

FIG. 1.—Average yields in tons per acre in 1951, the third harvest-year, and average numbers of plants per square foot in October 1951 of alfalfa strains and varieties. The values are averages of four locations in Maryland.

variety × location interactions may be more readily detected. *(3)* Varietal differences can be demonstrated at more locations, and superior varieties can be advertised more effectively. *(4)* The cost of establishment and maintenance of the auxiliary tests would be very small.

The Fate of Substituted Urea Herbicides in Agricultural Soils[1]

G. D. Hill, J. W. McGahen, H. M. Baker, D. W. Finnerty, C. W. Bingeman[2]

IN CONNECTION with the use of 3-(*p*-chlorophenyl)-1, 1-dimethylurea[3] and 3-(3,4-dichlorophenyl)-1,1-dimethylurea[3] for controlling weeds in crops, the question of herbicidal residues in soils must be answered. This is especially pertinent since these materials are noted for their long-term herbicidal effects when used at "sterilant" rates, usually above 20 pounds per acre.

[1] Contribution from Grasselli Chemicals Department, Experimental Station, E. I. du Pont de Nemours & Co., Inc., Wilmington, Dela. Rec. for publication Dec. 6, 1954. Complete publication cost paid by the du Pont Co.

[2] The assistance of M. B. Weed, A. W. Welch, J. R. Haun, V. L. Turner, B. L. Richards, Jr. and V. J. Fisher is gratefully acknowledged.

[3] Currently marketed under the trademarks "Karmex" W Herbicide and "Karmex" DL Herbicide, respectively.

Chemical and biological studies to determine the fate of these substituted urea herbicides in agricultural soils in the eastern half of the United States are described as outlined:

1. Studies on the rate of disappearance of the two compounds from various soil types after repeated annual applications of 1 to 2 pounds per acre:
   - *(a)* Field and greenhouse tests in which cover crops were grown as indicator plants on several representative soil types treated 4 to 6 months earlier;
   - *(b)* Chemical analyses of soil samples taken periodically from plots established on four soil types at four locations in the country.

2. Studies relating to the mechanisms by which these herbicides are decomposed or inactivated in soil:

(*a*) volatilization,
(*b*) leaching,
(*c*) chemical decomposition, and
(*d*) biological degradation.

Results from these studies indicate that when these herbicides are used annually for weed control in crops at rates of 1 to 2 pounds per acre, phytotoxic concentrations disappear from the soil within 4 to 8 months after application under the humid conditions prevalent in the eastern half of the United States. Annual applications result in no accumulation of practical significance. With annual applications of 4 pounds per acre, a somewhat longer time is required for disappearance than with lower rates. Under the same conditions as above, it has been found that a 4-pound per acre application is reduced to innocuous levels in cultivated soils 12 to 16 months after initial application. When tolerant crops such as asparagus are to be followed by crops which are more sensitive to the substituted ureas, the minimum amount of herbicide necessary for adequate weed control should be applied. When considerably higher amounts, 20 to 60 pounds per acre, are applied for "sterilant" use on noncultivated soils, a phytotoxic concentration often remains in the soil for 24 to 36 months.

Based on laboratory investigations, the disappearance of these herbicides from cultivated soil appears to be due primarily to biological degradation, although other factors such as leaching, volatilization, and chemical decomposition may play a part under certain conditions. The longer time required for the disappearance of these herbicides in non-cultivated soils may be attributed in part to the lower level of microbial activity encountered in areas which are bare of vegetation and not aerated by tillage.

REVIEW OF LITERATURE

A review of the literature shows that only a limited number of experiments have been conducted to follow the rate of disappearance of the urea herbicides in agricultural soils.

Loustalot *et al.* (3) concluded from laboratory studies in Puerto Rico that disappearance of 3-(*p*-chlorophenyl)-1,1-dimethylurea from the soil is dependent to a large extent on prevailing environmental conditions such as temperature, soil moisture, soil texture and other factors. They reported that a 5-pound per acre rate of 3-(*p*-chlorophenyl)-1,1-dimethylurea, when applied on a fertile sandy loam that was stored at 10° C. and a moisture level suitable for planting, was toxic to corn and velvet beans for ten weeks. A similar rate on soil samples stored at room temperature or 45° C. was non-toxic to velvet beans within 2 weeks and to corn within 10 weeks.

When samples of a fertile loamy soil were treated with a 5-pound per acre rate, 2 weeks, 4 weeks, and 10 weeks were required for phytotoxicity to disappear at 36, 20, and 11% moisture, respectively. It was found that a 1-pound rate, using velvet beans and sweet corn as indicator plants, was dissipated within 2 weeks after application at all moisture levels.

Ogle,[4] using crabgrass as an indicator plant, concluded that a 4-pound per acre rate of 3-(*p*-chlorophenyl)-1,1-dimethylurea was inactivated in muck soil after 12 weeks at 46° F., and after 3½ weeks at 96° F. Little or no loss of herbicidal activity was noted in a sand or a silt loam over a 12-week period at similar temperatures.

Danielson and Easley (2) found that a 5-pound per acre rate of 3-(*p*-chlorophenyl)-1,1-dimethylurea worked into a 5-inch layer of sandy loam soil was non-toxic to sweet corn and snap beans after 3 months with 11.5 inches of rainfall.

[4] Ogle, Robert E. Activity and fate of herbicides applied to soils. Purdue University doctoral thesis, 1953.

METHODS AND RESULTS

Determination of Residual Concentrations of Herbicides by Growth of Indicator Crops

One of the most obvious and practical methods for the determination of residual activity of herbicides in soils is the growth and evaluation of indicator crops in treated areas.

In the spring of 1952 field experiments were initiated to measure the residual activity of both 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea when applied at pre-emergence rates of 1 and 2 pounds per acre.[5] Tests were established on Leon–Immokalee sand at Palma Sola, Fla.; Cecil loamy sand at Raleigh, N. C.; and Keyport silt loam at Newark, Del. These plots were retreated in the spring of 1953 with both herbicides at 1 and 2 pounds per acre. At Raleigh, N. C., oats were sown as a cover crop in 1952 and in 1953, each time approximately 5 months after the herbicides were applied. In the case of the tests at Palma Sola, Fla., and Newark, Del., soil samples were removed at 0 to 4, 4 to 8, and 8 to 12-inch depths from the treated plots (1952) and the retreated plots (1952 and 1953) every 4 months over a 24-month period, taken into the greenhouse, and planted to oats.

Subsequent observations of the cover crops at each of the above locations indicated that the concentration of both compounds was reduced to innocuous levels in these soils. Table 1 summarizes the results obtained in the bioassay of Keyport silt loam at Newark, Del. These results are essentially identical with the results obtained at the other two locations.

In the spring of 1953 a grower-cooperator program involving 72 geographical locations was undertaken to evaluate the use of substituted urea herbicides as a pre-emergence treatment on cotton at rates of 1.2 to 1.6 pounds. At 4 to 6 months after treatment, the growth of cover crops and winter annual weeds at 37 of these locations was observed. The crops and weeds were unaffected by the earlier herbicidal treatments. Cover crops included vetch, sweet clover, crimson clover, barley, rye, winter wheat, and winter oats. The remaining 35 locations had been plowed or disked and could not be evaluated.

Relationship between Rate of Disappearance of Herbicides and Possible Accumulation with Continued Use

When a chemical is applied to the soil year after year, the following considerations indicate that there should be no continuous accumulation or build-up provided a substantial fraction of the material disappears from the soil each year.

In the general case, where a fraction (X) of the material remains in the soil each year and where (A) is the application rate each year:

After one year, the residue (R) is AX; then (A) pounds per acre is applied.
After two years, $R = (A + AX)X = AX + AX^2$.
After (n) years, $R = AX + AX^2 \ldots AX^n$ where (R) is the residue at the end of the n^{th} year just prior to the next annual application. This equation can be transformed to:

$$R = \frac{AX(1-X^n)}{(1-X)}$$

By the use of the general formula above, the possible cumulative level of any chemical, when applied at the rate of one unit per acre per year for a given number of years, has been calculated and depicted graphically in figure 1.

Illustrating with a typical example, it is assumed that 1 pound per acre (A) of a chemical is applied in the spring of each year for 3 years and that 90% of the material disappears each year (X = 0.10). The important question is, "How much is going to remain if the original treatment of 1 pound is repeated year after year for 3 years?"

[5] All rates and concentrations are expressed on an active ingredient basis.

Year	Amount applied	Amount remaining at end of year
1952	1 pound	0.1 pound
1953	1 pound	0.01+0.1 pound=0.11 pound
1954	1 pound	0.001+0.01+0.1 pound=0.111 pound

Thus, 3 pounds were applied in 3 years, but only 0.111 pound remains at the end of the third year. Figure 1 indicates that, if 1 pound per year is applied for 10 years, less than 0.12 pound should be present in the soil at the end of the tenth year and prior to reapplication. Further, if we assume that 75% of the chemical disappears each year, the maximum amount that remains in the soil should never exceed one-third of the amount applied in a single application.

The data presented in table 2 represent results of field studies over a 2-year period on the rate of disappearance of the substituted urea herbicides. It is evident that the major portion of the materials is disappearing each year and that there is little need for concern over "build-up" in the soil.

The assumption, stated above, that a certain fraction of the material disappears each year, corresponds to a "first-order" differential equation, that is, the rate of disappearance is proportional to the amount left in the soil:

$$\frac{dx}{dt} = k.x$$

where x = amount present in soil at time (t), and (k) is a constant for any given soil and set of conditions. Integration gives:

$$\log \frac{x_0}{x} = kt$$

where (x_0) is the amount present where (t) = 0.

In an example, a heavy application of 3-(*p*-chlorophenyl)-1,1-dimethylurea was applied to an unclassified loam at Minquadale, Del., and after various periods of time, samples were taken to a depth of 12 inches and analyzed. All of the herbicides recovered was present in the upper 4 inches of soil. The original concentration in the upper 4-inch layer was 18 ppm. (based on air-dried soil), which is the value for x_0. The values of x_0/x are calculated below. If the first-order equation is applicable,

$$\frac{\log (x_0/x)}{t} = k$$

As shown by the calculations below, the value of k is essentially constant over a five-fold range of values of x_0/x. This shows that the assumption on which the equation is based is valid.

While variable soil moisture and temperature conditions may often accelerate or retard the rate of removal, it is believed that on the average, the first-order equation is applicable under usual field conditions.

Soil sampled after treatment	Herbicide remaining	$\frac{x^\circ}{x}$	k
Weeks	x (as ppm.)		
1	15.2	1.18	0.079
3	10.6	1.70	0.077
6	5.6	3.21	0.084
10	3.5	5.13	0.071

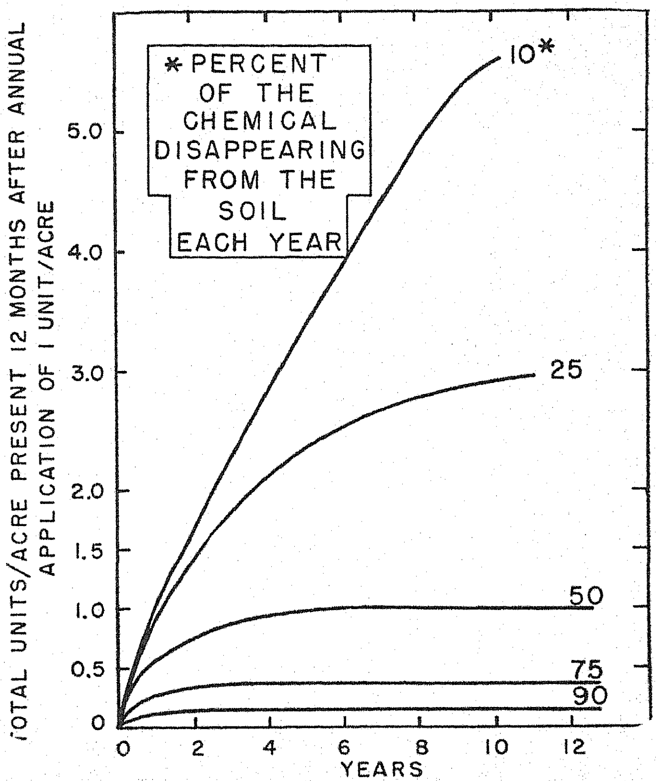

FIG. 1.—Theoretical cumulative level of a chemical in soil when one unit per acre per year is applied.

Determination of Residual Concentrations of Herbicides by Chemical Analyses

The use of biological tests for determining the amount of herbicidal residues in soil as well as measuring any possible "build-up" or cumulation is a practical but nevertheless indirect method and should be complemented by direct chemical analyses. By sensitive chemical analyses, it is possible to follow the rate of disappearance and thus detect any trends toward possible phytotoxic accumulations long before similar information could be obtained by biological assays. However, the importance of biological tests for determining whether the residue is phytotoxic to succeeding crops should not be minimized.

Experiments.—To measure the rate of disappearance of 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea over a range of soil types and weather conditions, plots were established in the spring of 1952 on Leon–Immokalee sand at Palma Sola, Fla.; Cecil loamy sand at Raleigh, N. C.; Lintonia silt loam at Essen Lane, La.; and Keyport silt loam at Newark, Del. A portion of each plot was retreated in the spring of 1953. Soil samples for chemical analyses were removed periodically, every 4 months, at 0 to 4, 4 to 8, and 8 to 12-inch depths from both the treated (1952) and retreated (1952 and 1953) plots. In addition, several soil samples representative of a range of soil types were obtained for analysis from field plots treated with formulations of 3-(3,4-dichlorophenyl)-1,1-dimethylurea and with isopropyl N-(3-chlorophenyl)-carbamate (3-CIPC) in 1953 by state investigators and by du Pont personnel.

The analytical method as described by Bleidner *et al.* (1) for 3-(*p*-chlorophenyl)-1,1-dimethylurea with minor changes for 3-(3,4-dichlorophenyl)-1,1-dimethylurea and isopropyl N-(3-chlorophenyl)-carbamate was used for the chemical determination of residues in treated soils. This procedure includes the alkaline hydrolysis of 3-(*p*-chlorophenyl)-1,1-dimethylurea or 3-(3,4-dichlorophenyl)-1,1-dimethylurea in treated soils to *p*-chloroaniline or 3,4-dichloroaniline which is determined colorimetrically. Also, an untreated soil sample is analyzed for apparent *p*-chloroaniline or apparent dichloroaniline content and net value for the treated

Table 1.—Response of oats grown in the greenhouse on samples of Keyport silt loam (0–4 inch depth) removed from the field after pre-emergence treatments with 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Newark, Del.

Treatment	Date of treatment	Soil sampled after treatment	Oats response: Injury rating* 26 days after planting	Oats response: Weight per plant expressed as percent of check, green	Oats response: Weight per plant expressed as percent of check, dry
lb./A		months		%	%
3-(*p*-Chlorophenyl)-1-dimethylurea					
1	June 18, 1952	4	0.0	—	—
1+1†	(June 18, 1952)	4	0.0	87	89
	(June 22, 1953)	8	0.0	124	105
2	June 18, 1952	4	0.0	—	—
2+2†	(June 18, 1952)	4	2.0	93	80
	(June 22, 1953)	8	0.4	126	97
		12	0.7	115	104
3-(3,4-Dichlorophenyl)-1,1-dimethylurea					
1	June 18, 1952	4	0.0	—	—
1+1†	(June 18, 1952)	4	0.0	106	100
	(June 22, 1953)				
2	June 18, 1952	4	0.0	—	—
2+2†	(June 18, 1952)	4	0.0	88	80
	(June 22, 1953)	8	0.0	132	109

* Plants rated on a 0–4 basis: 0 = no visible injury, 4 = all plants dead.
† Plots were treated at 1 or 2 pounds per acre, as designated, in 1952 and retreated in 1953. Soil samples were taken at 4-month intervals after the 1953 application.

Table 2.—Disappearance (percent) of 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea in various soils after repeated treatments.

Herbicide	Soil	Year	Rate	Disappearance during 12 months
			lb./A.	%
3-(*p*-Chlorophenyl)-1,1-dimethylurea	Lintonia silt loam, Essen Lane, La.	1952	1	84
		1952 and 1953	1+1	69*
		1952	2	98
		1952 and 1953	2+2	76*
3-(3,4-1-Dichlorophenyl)-1,1-dimethylurea	Lintonia silt loam, Essen Lane, La.	1952	1	85
		1952 and 1953	1+1	89*
3-(*p*-Chlorophenyl)-1,1-dimethylurea	Cecil loamy sand, Raleigh, N. C.	1952	1	87
		1952 and 1953	1+1	91
		1952	2	89
		1952 and 1953	2+2	71
3-(3,4-Dichlorophenyl)-1,1-dimethylurea	Cecil loamy sand, Raleigh, N. C.	1952	1	78
		1952 and 1953	1+1	80
3-(*p*-Chlorophenyl)-1,1-dimethylurea	Leon–Immokalee sand, Palma Sola, Fla.	1952	1	87
		1952 and 1953	1+1	73
3-(3,4-Dichlorophenyl)-1,1-dimethylurea	Leon–Immokalee sand, Palma Sola, Fla.	1952	1	85
		1952 and 1953	1+1	87*
				Av. 83

* 8 months.

sample is determined by difference. All soils contain some naturally-occurring materials which interfere with the analysis. Since the amount of these materials varies in different soils and in a given soil, the figure obtained by analysis of the untreated soil is not absolute. Hence, treated soils which analyze no more than an untreated check are not reported as containing zero residue but as containing less than one-half of the blank. This is believed to be the significant level of detection. The figures represent the maximum possible amount of herbicide present, since the method measures the presence of either chloroanilines or materials which hydrolyze to chloroanilines. Thus, the method detects 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea and any intermediate breakdown products which would hydrolyze to the chloroanilines.

Results.—When the results of chemical analyses are depicted graphically in this paper, a line denoting one-half of the blank for that particular soil is included. For all practical purposes, this line represents the average effective *zero* line for that soil.

The results of chemical analyses of soil samples taken at 4, 8, and 12 months after the original treatment and 4, 8 and 12 months after retreatment from plots which received 1 and 2 pounds per acre of 3-(*p*-chlorophenyl)-1,1-dimethylurea or 3-(3,4-dichlorophenyl)-1,1-dimethylurea as a blanket application at Newark, Del.; Raleigh, N. C.; Palma Sola, Fla., and Essen Lane, La. are given in figures 2 through 17. No samples were obtained at 12 months after retreatment at Newark, Del. and Essen Lane, La. Results from all locations are presented for the 0 to 4 inch depth with the initial treatments (1952) and the 0 to 8 inch depth for the retreatments (1952 and 1953). The residue found after treatment was present in the 0 to 4 inch layer, with negligible amounts at 4 to 8 inches, and none in the 8 to 12 inch layer.

The data indicate that these compounds disappear from the soils at about the same rate. The residual portions were not present in phytotoxic concentrations, as manifested by the normal growth of oats planted at three of the locations involved.

Results of analyses of soil samples from tests with 3-(3,4-dichlorophenyl)-1,1-dimethylurea by state investigators and by du Pont personnel are recorded in tables 3, 4, and 5. These data follow the same general pattern in that the concentrations of 3-(3,4-dichlorophenyl)-1,1-dimethylurea were reduced to relatively low levels after 4 months. In a comparison of the relative breakdown rates of 3-CIPC and 3-(3,4-dichlorophenyl)-1,1-dimethylurea (table 5), it was found that a 12-pound rate of 3-CIPC disappeared from the soil at the rate of 7 to 15% per month, while a 2-pound

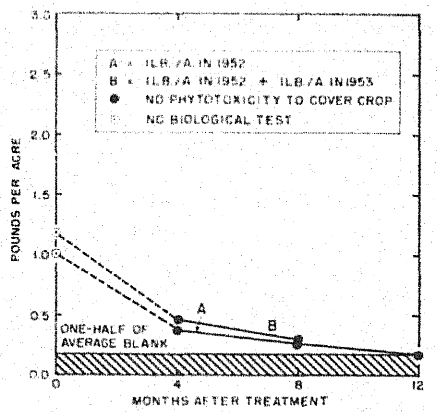

FIG. 2.—Chemical analyses of Keyport silt loam after treatment with 3-(*p*-chlorophenyl)-1,1-dimethylurea at Newark, Del.

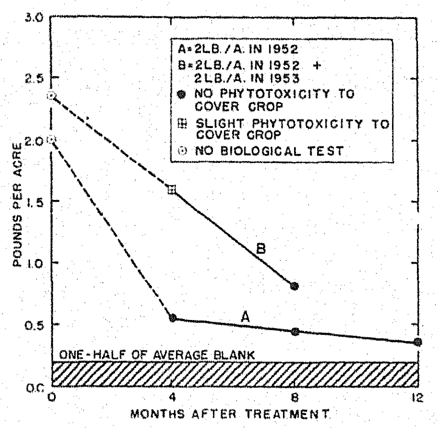

FIG. 3.—Chemical analyses of Keyport silt loam after treatment with 3-(*p*-chlorophenyl)-1,1-dimethylurea at Newark, Del.

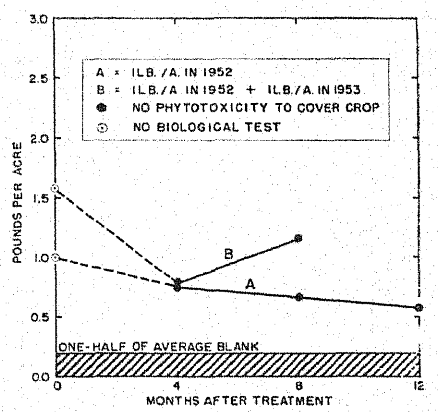

FIG. 4.—Chemical analyses of Keyport silt loam after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Newark, Del.

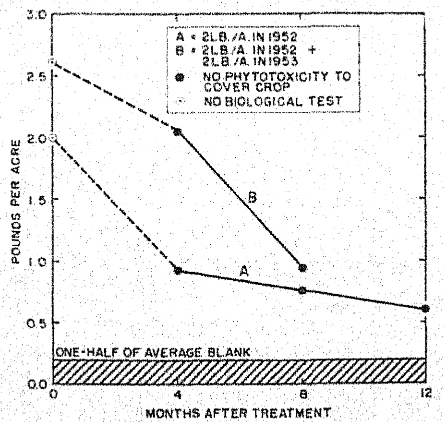

FIG. 5.—Chemical analyses of Keyport silt loam after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Newark, Del.

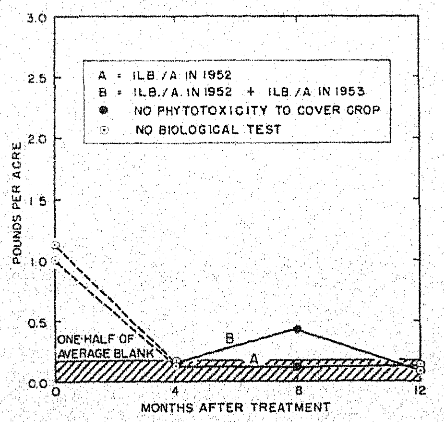

FIG. 6.—Chemical analyses of Cecil loamy sand after treatment with 3-(*p*-chlorophenyl)-1,1-dimethylurea at Raleigh, N. C.

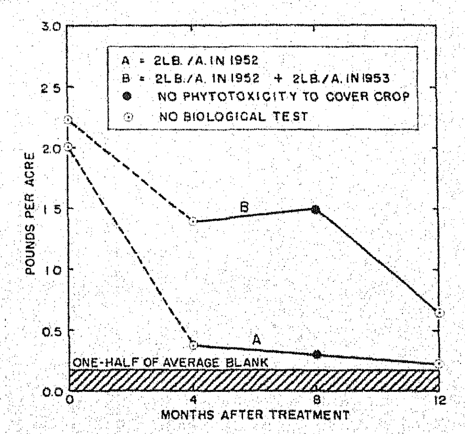

FIG. 7.—Chemical analyses of Cecil loamy sand after treatment with 3-(*p*-chlorophenyl)-1,1-dimethylurea at Raleigh, N. C.

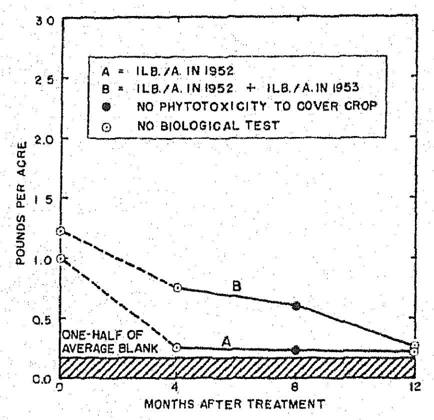

FIG. 8.—Chemical analyses of Cecil loamy sand after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Raleigh, N. C.

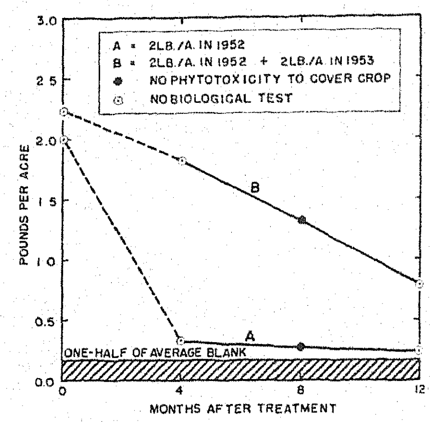

FIG. 9.—Chemical analyses of Cecil loamy sand after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Raleigh, N. C.

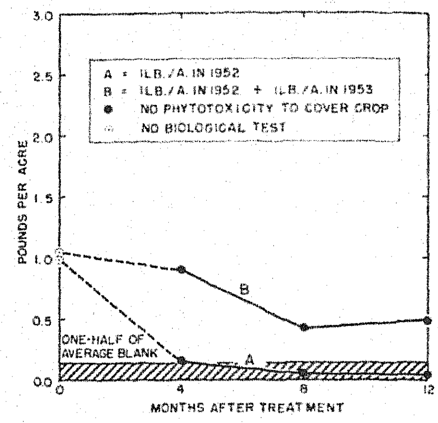

FIG. 10.—Chemical analyses of Leon–Immokalee sand after treatment with 3-(*p*-chlorophenyl)-1,1-dimethylurea at Palma Sola, Fla.

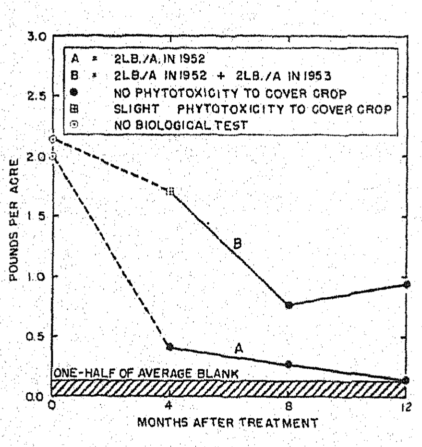

FIG. 11.—Chemical analyses of Leon–Immokalee sand after treatment with 3-(*p*-chlorophenyl)-1,1-dimethylurea at Palma Sola, Fla.

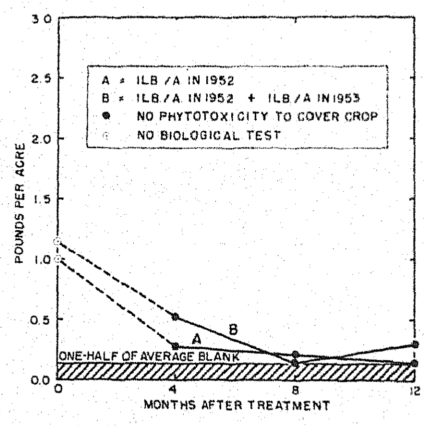

FIG. 12.—Chemical analyses of Leon–Immokalee sand after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Palma Sola, Fla.

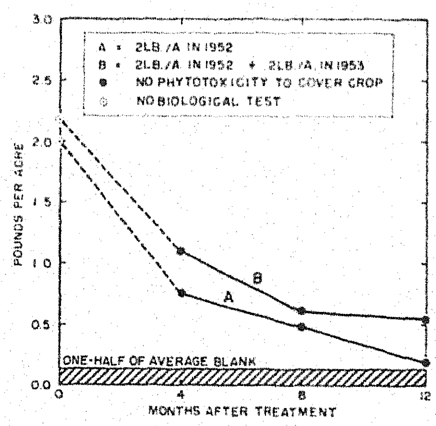

FIG. 13.—Chemical analyses of Leon–Immokalee sand after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Palma Sola, Fla.

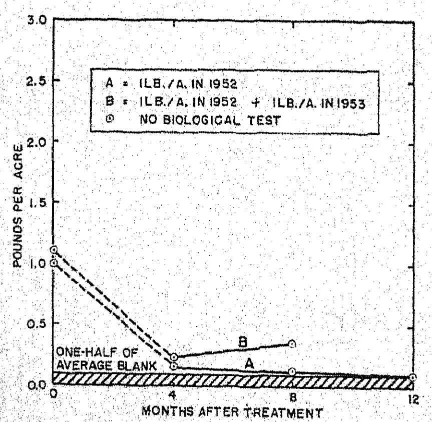

FIG. 14.—Chemical analyses of Lintonia silt loam after treatment with 3-(*p*-chlorophenyl)-1,1-dimethylurea at Essen Lane, La.

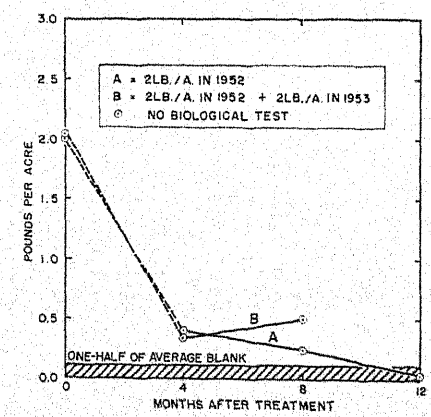

FIG. 15.—Chemical analyses of Lintonia silt loam after treatment with 3-(*p*-chlorophenyl)-1,1-dimethylurea at Essen Lane, La.

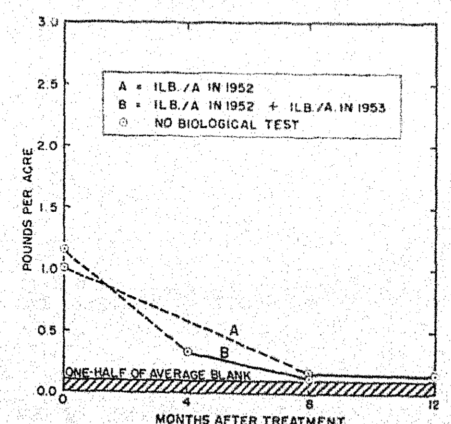

FIG. 16.—Chemical analyses of Lintonia silt loam after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Essen Lane, La.

Table 3.—Results of chemical analyses of soil samples (0–4 inch depth) after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea. State Investigator Cotton Program.

Location	Soil type	Rate	Soil sampled after treatment	Net amount found		Loss per month
		lb./A.	months	ppm.	lb./A.	%
Clemson Agr. College, Clemson, S. C.	Lloyds clay loam	1	6	<0.51	——	——
		2	6	1.29	0.78	10.2
Oklahoma A & M College, Stillwater, Okla.	Yahloa fine sandy loam	1	6	<0.24	——	——
		2	6	0.80	0.78	10.2
Mississippi State College, State College, Miss.	Una clay loam	1	4	0.64	0.60	10.0
		2	4	0.64	0.45	19.4
North Carolina State College, Raleigh, N. C.	Norfolk sandy loam	1	5.5	<0.17	——	——
		2	5.5	0.34	0.39	14.6
Delta Branch Exp. Sta., Stoneville, Miss.	Bosket fine sandy loam	1	4	0.28	0.22	19.5
		2	4	1.08	0.90	13.8
West Tennessee Exp. Sta., Jackson, Tenn.	Lintonia silt loam	1	2	0.61*	——	——
Texas A & M College, College Station, Tex.	Miller clay	2	5	0.73*	——	——

* Apparent ppm.—no untreated samples received, thus net ppm. could not be calculated.

Table 4.—Results of chemical analyses of soil samples (0–4 inch depth) at 4 months after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea. Grower-Cooperator Program.

Location	Soils	Rate	Net amount found		Loss per month
		lb./A.	ppm.	lb./A.	%
St. Joseph, La.	Sandy loam	1.7	0.49	0.41	18.9
Indianola, Miss.	Sandy loam	1.7	1.20*	——	——
Era, Tex.	Clay	1.6	1.03	0.83	12.2
Sidon, Miss.	Sandy loam	1.8	<0.33	<0.18	——
Athens, Ga.	Cecil sandy loam	1.6	<0.50	<0.24	——
Mira, La.	Sandy loam	1.2	<0.21	<0.16	——
Cedar Bluffs, Ala.	Holstun sandy loam	1.6	0.92	0.56	16.3
Scott, Miss.	Sandy loam	1.3	0.76*	——	——
Victoria, Tex.	Lake Charles clay	1.4	0.67*	——	——
El Campo, Tex.	Sandy loam	1.6	0.50	0.13	22.9
Melville, La.	Sandy silt loam	1.3	0.41	0.15	22.1
Winnsboro, La.	Fine sandy loam	1.2	<0.23	<0.15	——

* Apparent ppm.—no untreated samples received, thus net ppm. could not be calculated.

rate of 3-(3,4-dichlorophenyl)-1,1-dimethylurea disappeared at the rate of 4 to 13.5% per month. Both compounds disappeared from the various soils at rates that appear favorable to repeated use.

Mechanisms Relating to Disappearance of Herbicides from Soils

In general, herbicides may disappear from the soil by physical means such as volatilization and leaching, by chemical means such as hydrolysis, oxidation, and photodecomposition (ultra-violet irradiation), and by biological degradation. Experiments were initiated to evaluate the importance of these factors in the disappearance of substituted urea herbicides.

Volatilization

At 25° C., 3-(*p*-chlorophenyl)-1,1-dimethylurea, a typical member of this group of herbicides, has a vapor pressure of 5×10^{-7} mm. Hg. in contrast to the isopropyl ester of 2,4-D with a vapor pressure of 10.5×10^{-3} mm. Hg. The substituted urea herbicide is approximately 20,000 times less volatile. In view of this extremely low vapor pressure at ordinary temperatures, loss of this compound from the soil by volatilization is likely to be a minor factor under field conditions, where frequent rains would move the compound into the soil. Volatilization could be expected to be a significant factor in situations where the herbicide is applied to the surface of dry soil and remains on the surface for extended periods during hot, dry weather.

Leaching

Leaching through the soil and beyond the root zone might serve as an avenue for disappearance of an herbicide. The amount of leaching in a soil depends on the solubility of the compound, distribution and intensity of rainfall, soil

Table 5.—Results of chemical analyses of soil samples (0–4 inch depth) after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea and isopropyl-N-(3-chlorophenyl)-carbamate.

Soil type and location	Treatment	Rate	Soil sampled after treatment	Net amount found		Loss per month
		lb./A.	months	ppm.	lb./A.	%
Commerce silt loam, Chamberlain, La.	3-(3,4-dichlorophenyl)-1,1-dimethylurea	2	5	0.80	0.65	13.5
	3-CIPC	12	5	2.83	2.44	15.9
Commerce silt loam, Chamberlin, La.	3-(3,4-dichlorophenyl)-1,1-dimethylurea	2	7.5	0.51*	—	—
	3-CIPC	12	7.5	1.67*	—	—
Cecil loamy sand, Raleigh, N. C.	3-(3,4-dichlorophenyl)-1,1-dimethylurea	2	9	0.80	1.27	4.1
	3-CIPC	12	9	1.23	2.04	9.2
Leon–Immokalee sand, Bradenton, Fla.	3-(3,4-dichlorophenyl)-1,1-dimethylurea	1	10	<0.16	<0.12	8.8
		2	10	0.32	0.21	9.0
	3-CIPC	12	10	0.34	0.21	9.8
Commerce silt loam, St. Joseph, La.	3-(3,4-dichlorophenyl)-1-1-dimethylurea	1	12	<0.15	<0.17	6.9
		2	12	<0.15	<0.13	7.8
	3-CIPC	12	12	0.25	0.28	8.1
Lintonia silt loam, Essen Lane, La.	3-(3,4-dichlorophenyl)-1,1-dimethylurea	2	12	<0.34	<0.37	6.8
	3-CIPC	12	12	0.81	0.80	7.8

* Apparent ppm.—no untreated samples received, thus net ppm. could not be calculated.

characteristics such as soil texture and soil structure, and the amount of organic matter present.

Experiments.—Eleven soil types at seven locations in the United States were removed from the field in 0 to 6, 6 to 12, and 12 to 36-inch increments. The respective soil increments were placed in lysimeters (8 inches in diameter and 36 inches tall) in the greenhouse and packed in an effort to simulate as nearly as possible soil profiles existing under field conditions. The respective soils in these lysimeters were wetted daily so as to settle the soil and thus prevent channeling of water through the soil columns. 3-(*p*-chlorophenyl)-1,1-dimethylurea was applied to the surface of each column at the rate of 10 pounds per acre, and the columns leached with the equivalent of 72 surface inches of simulated rainfall. The artificial rainfall pattern was such that 1 inch of rainfall was applied each day for 5 days. After 2 days had elapsed, 1 inch of rainfall was applied again each day for 5 days and the same procedure repeated until the total amount of water had been applied over a period of approximately 90 days. The temperature in the greenhouse varied from approximately 65° to 95° F. during the study. Leachate samples were collected in 1-gallon bottles containing 2 gm. HgCl to prevent growth of microorganisms. Upon completion of the leaching phase, the soils were removed from the lysimeters in separate 4-inch layers and analyzed.

Results.—Table 6 shows that the amount of 3-(*p*-chlorophenyl)-1,1-dimethylurea remaining in the soils after leaching varied from 4 to 62%. That found in the leachate varied from 0 to 56%, and that unaccounted for varied from 38 to 85%. These laboratory data indicate that some leaching can occur when large volumes of water are used, representing extremely high effective rainfall on a porous soil. However, under crop treatment conditions, removal of 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea from the soil by percolation is believed not to be a major factor, since after application of 1 to 2 pounds per acre the results of numerous soil analyses indicated that essentially no herbicide was present below a depth of 4 inches.

It is significant that 38 to 85% of the amount applied in the lysimeter study was not accounted for. Subsequent studies were initiated to determine whether chemical decomposition and biological degradation could account for this loss.

Table 6.—Results of lysimeter leaching study—material balance on a 10-pound per acre application of 3-(*p*-chlorophenyl)-1,1-dimethylurea after leaching with the equivalent of 72 surface inches of water.

Soil type and location	Found in soil	Found in leachate	Unaccounted for
	%	%	%
Sandy clay loam, Manhattan, Kans.	62	0	38
Cecil clay Raleigh, N. C.	4	56	40
Unclassified muck Bradenton, Fla.	53	0	47
Unclassified clay loam Manhattan, Kans.	49	1	50
Leon–Immokalee sand Bradenton, Fla.	11	30	59
Commerce silt loam Baton Rouge, La.	40	0	60
Unclassified sand Dover, Del.	23	16	61
Unclassified loam Eagle Pass, Tex.	4	30	66
Cecil loamy sand Raleigh, N. C.	12	15	73
Unclassified loam Minquadale, Del.	17	0	83
Lintonia silt loam Baton Rouge, La.	10	5	85

CHEMICAL DECOMPOSITION

The role of chemical decomposition in the disappearance of the urea herbicides from the soil is a difficult factor to evaluate. Preliminary results from a series of experiments still in progress indicate that both 3-(*p*-chlorophenyl)-1,1-

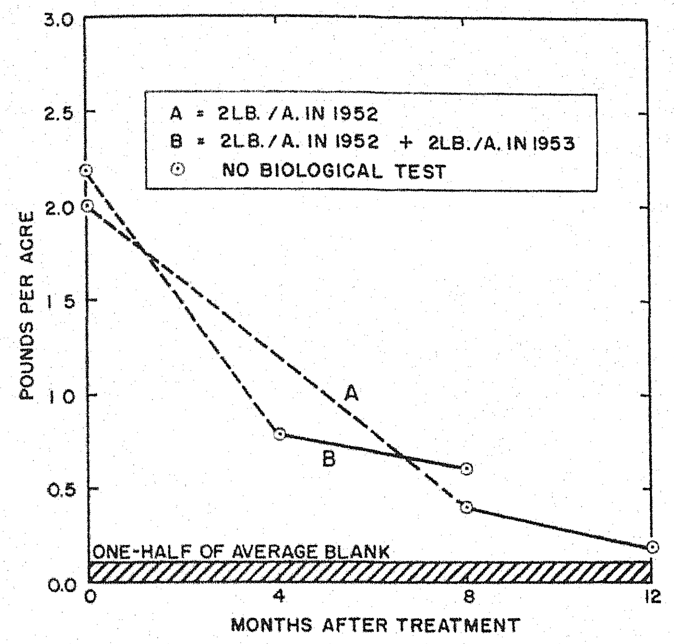

FIG. 17.—Chemical analyses of Lintonia silt loam after treatment with 3-(3,4-dichlorophenyl)-1,1-dimethylurea at Essen Lane, La.

dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea are stable in aqueous solution and that disappearance from the soil by non-biological decomposition is probably not important in most cases.

In studies on the role of photodecomposition on the fate of these herbicides, it was shown that an 83% loss of 3-(*p*-chlorophenyl)-1,1-dimethylurea occurred when a standard solution containing 88.3 ppm. in glass-distilled water and sealed in quartz tubes was exposed to sunlight for 48 days. This may explain the disappearance of the herbicide from the soil surface in the dry areas of the West and Southwest when little rainfall occurs after application, and the chemical remains on the soil surface. However, ultra-violet irradiation would be expected to account for the disappearance of only a small portion of the herbicide in more humid areas where frequent rains would move the chemical into the soil. In the case of the lysimeter leaching study in the greenhouse, described above, irradiation can be disregarded as a factor in the disappearance of 3-(*p*-chlorophenyl)-1,1-dimethylurea since the soils were not exposed appreciably to ultra-violet irradiation.

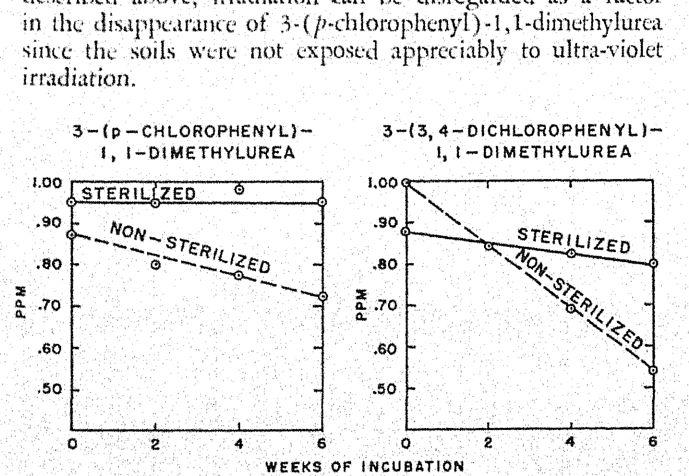

FIG. 18.—Results of bioassay of sterilized and non-sterilized samples of Cecil loamy sand treated with 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea and incubated at 80° F.

BIOLOGICAL DEGRADATION

In addition to determining the effect of soil microorganisms in the disappearance of urea herbicides, it is equally important to find out the effect of these compounds on the soil microflora. By use of the dilution plate technique, it was found that 3-(*p*-chlorophenyl)-1,1-dimethylurea applied to agar medium to form a concentration of 250 ppm. had no adverse effect on the microbe population. Studies were conducted on the microbe population of soil samples removed in May 1954 from field plots which received a 4-pound per acre application, 2 pounds in 1952 and 2 pounds in 1953, of 3-(3,4-dichlorophenyl)-1,1-dimethylurea. In a comparison of treated and non-treated soil samples, no quantitative or qualitative differences among bacteria, fungi, yeasts, and actinomyces were noted.

Loustalot *et al.* (3) concluded that the decomposition of 3-(*p*-chlorophenyl)-1,1-dimethylurea in soil was hastened by those factors favoring soil microbial action such as warm temperature, adequate moisture supply, and the presence of organic matter.

Inactivation in sterilized and non-sterilized soils: Experiments.—To determine whether inactivation of these herbicides is due to chemical decomposition or microbial degradation, experiments were conducted on the rate of disappearance of 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea in sterilized and non-sterilized soils. Both compounds were applied to Cecil loamy sand at the rate of 1 ppm., based on the weight of air-dry soil. All samples were watered and one-half of the samples were sterilized with chloropicrin. Both the sterilized and non-sterilized samples were stored at 80° F. and 60% relative humidity. No leaching occurred in this experiment. The soil was retained in wide-shoulder jars which were covered with cotton to minimize evaporation. Representative soil samples were removed from storage at 0, 2, 4, and 6 weeks and planted to oats to measure the concentration of herbicide. Results of the bioassay of soil samples at 26 days after planting are reported in figure 18.

The data show that the rate of inactivation was greater in non-sterilized than in sterilized soils, and suggest that soil microbes play a definite role in the degradation of both urea herbicides.

A similar type of experiment was conducted in which non-sterilized samples of Cecil loamy sand and of Brookston silty clay loam were treated at a concentration of 1 and 5 ppm., respectively, with both herbicides prior to the 0 to 6 weeks incubation period. These samples were retreated each time prior to the 6 to 12, 12 to 18, and 18 to 22 weeks incubation periods, to equal a concentration of 4 and 20 ppm. for the Cecil and Brookston soils, respectively. It was anticipated that such a method of accelerated retreatment every 6 weeks would be most valuable in predicting the rate of disappearance of these herbicides. Chemical analyses were made on representative soil samples removed from storage after each incubation period, but prior to retreatment, at 6, 12, 18, and 22 weeks.

Results.—Figures 19 through 22 summarize the rate of breakdown of both compounds in the Cecil and Brookston soils. In the Cecil loamy sand with a total application of 4 ppm., during 22 weeks there was a 45% loss of 3-(*p*-chlorophenyl)-1,1-dimethylurea and a 38% loss of 3-(3,4-dichlorophenyl)-1,1-dimethylurea. In the case of the Brookston soil with a total application of 20 ppm., a 38% loss of 3-(p-chlorophenyl)-1,1-dimethylurea and a 43% loss of 3-(3,4-dichlorophenyl)-1,1-dimethylurea was indicated. From these results it is concluded that soil microflora are active in the decomposition of these herbicides. Although the compounds were added more rapidly than breakdown occurred, there was a fairly constant rate of breakdown throughout the duration of the experiment, thus indicating that retreatments did not retard the rate of breakdown by the soil microbes.

Decomposition of C^{14} methyl-labeled 3-(p-chlorophenyl)-1,1-dimethylurea (4) *in soil: Experiment.*—Studies were initiated to in-

vestigate the rate and extent of attack of soil microorganisms on C^{14} methyl-labeled 3-(*p*-chlorophenyl)-1,1-dimethylurea. Samples of clay loam with a clay content of 30% and an organic matter content of 2.8% were treated with the C^{14}-labeled material at a concentration of 2 ppm., based on weight of air-dry soil, and placed in a system so that moist air flowed upward through the soil into acidic and basic traps. Samples from the basic trap were radio-assayed each 15 days over a 3-month period.

Results.—The percent decomposition of the C^{14}-labeled 3-(*p*-chlorophenyl)-1,1-dimethylurea at room temperature over a 90-day period is depicted graphically in figure 23. These data show that approximately 10% of the compound was decomposed in 90 days, as evidenced by the evolution of $C^{14}O_2$. A steady rate of breakdown was evident for approximately 70 days, after which the rate decreased. The leveling of the curve may be due to depletion of metabolizable compounds necessary for high microbial activity in the soil. These results are interpreted as further indication that soil microbes are instrumental in the decomposition of the substituted urea herbicides in soils.

Oxidation of 3-(p-chlorophenyl)-1,1-dimethylurea by soil microorganisms: Experiment.—Bacteria isolated from a Brookston silty clay loam were tested for their ability to oxidize 3-(*p*-chlorophenyl)-1,1-dimethylurea.

A soil bacterium of the *Pseudomonas* group was isolated from a non-herbicide treated Brookston soil in nutrient agar containing 3-(*p*-chlorophenyl)-1,1-dimethylurea. The organisms were maintained on tryptone-yeast extract-3-(*p*-chlorophenyl)-1,1-dimethylurea (400 ppm.)-agar medium. The cells of this bacterium were grown in an inorganic salt-sodium glutamate medium with 3-(*p*-chlorophenyl)-1,1-dimethylurea (400 ppm.) as an energy source. Cells from 16-hour cultures were collected by centrifugation, suspended in a phosphate buffer of pH 7 and added to Warburg cups at 4 to 5 mgm. dry weight per cup. 3-(*p*-chlorophenyl)-1,1-dimethylurea was used as a substrate at 0.4×10^{-3} *M*, 0.3×10^{-3} *M*, and 0.2×10^{-3} *M*. The water bath temperature was maintained at 86° F. The curves in figure 24 show that oxidation began immediately after the compound was introduced and that the total oxygen uptake increased with increasing amounts of the herbicide.

A bacterium of the *Pseudomonas* group was isolated from a sample of 3-(*p*-chlorophenyl)-1,1-dimethylurea-treated Brookston soil and cultured as described previously. 3-(*p*-chlorophenyl)-1,1-dimethylurea was used as a substrate at 10^{-3} *M*, 1 ml. per Warburg cup. Yeast extract was tipped in after addition of the substrate at the rate of 1 mgm. per cup. Oxidation of 3-(*p*-chloro-

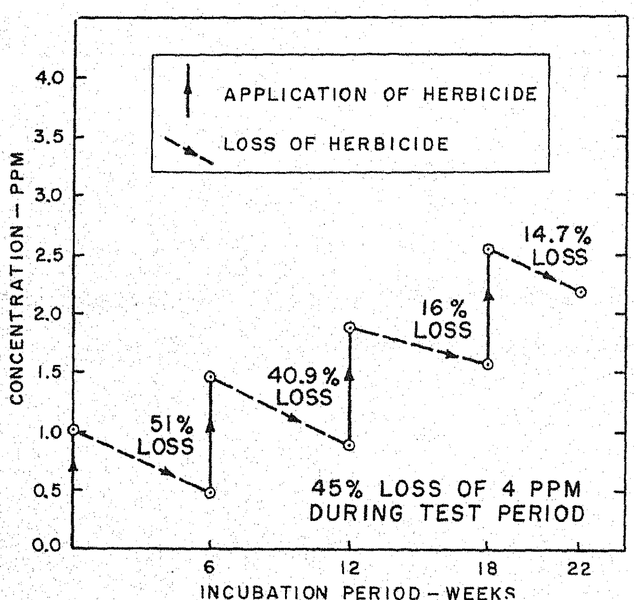

FIG. 19.—Decomposition (percent) of 3-(*p*-chlorophenyl)-1,1-dimethylurea as determined by chemical analyses of Cecil loamy sand incubated at 80° F. in the laboratory; samples treated with 1 ppm. prior to each incubation period to total 4 ppm.

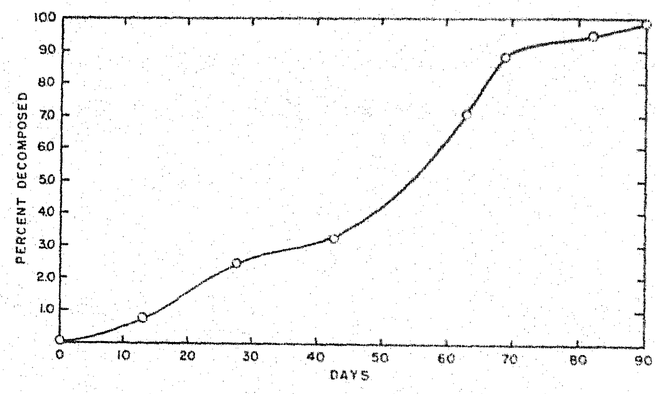

FIG. 23.—Decomposition (percent) of a 2 ppm. concentration of C^{14} methyl-labeled 3-(*p*-chlorophenyl)-1,1-dimethylurea in unclassified clay loam in a laboratory study as measured by radio-assay.

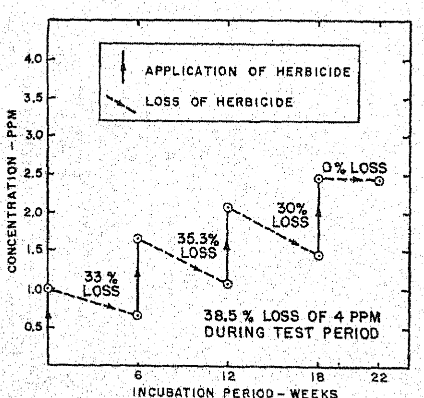

FIG. 20.—Decomposition (percent) of 3-(3,4-dichlorophenyl)-1,1-dimethylurea as determined by chemical analyses of Cecil loamy sand incubated at 80° F. in the laboratory; samples treated with 1 ppm. prior to each incubation period to total 4 ppm.

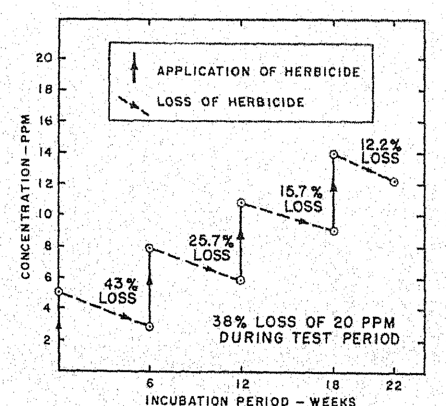

FIG. 21.—Decomposition (percent) of 3-(*p*-chlorophenyl)-1,1-dimethylurea as determined by chemical analyses of Brookston silty clay loam incubated at 80° F. in the laboratory; samples treated with 5 ppm. prior to each incubation period to total 20 ppm.

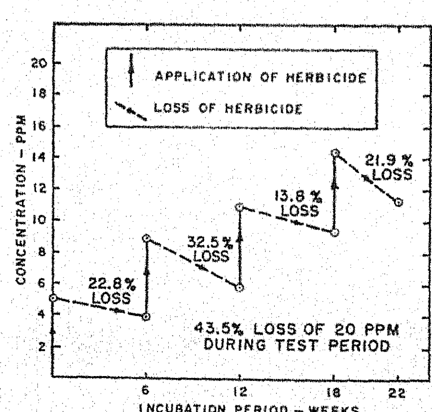

FIG. 22.—Decomposition (percent) of 3-(3,4-dichlorophenyl)-1,1-dimethylurea as determined by chemical analyses of Brookston silty clay loam incubated at 80° F. in the laboratory; samples treated with 5 ppm. prior to each incubation period to total 20 ppm.

phenyl)-1,1-dimethylurea proceeded rapidly upon addition of the yeast extract (figure 25), indicating that some essential factor present in the yeast extract was necessary for oxidation.

Results.—It was shown by these experiments that some microorganisms are capable of oxidizing 3-(*p*-chlorophenyl)-1,1-dimethylurea and use this compound as a sole source of carbon. Also, there are other soil microorganisms which are capable of oxidizing this compound if accessory growth factors found in organic materials such as yeast extract are present. These growth factors normally will be found in the soil organic matter or soil mineral matter and, therefore, both types of organisms probably are active in the decomposition of 3-(*p*-chlorophenyl)-1,1-dimethylurea under field conditions. The microorganisms used in these tests are common soil inhabitants and can be expected to be present in all agricultural soils.

SUMMARY

Studies were conducted to measure the rate of disappearance of 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea under field conditions over a 2-year period from plots established on Keyport silt loam at Newark, Del.; Cecil loamy sand at Raleigh, N. C.; Leon-Immokalee sand at Palma Sola, Fla.; and Lintonia silt loam at Essen Lane, La. On the basis of chemical analyses and the growth of cover crops, it was concluded that when these herbicides are applied initially at rates of 1 to 2 pounds per acre as a blanket treatment, followed by a retreatment 12 months later, phytotoxic concentrations disappear from the soil within 4 to 8 months after each treatment. Under the humid conditions prevalent in the eastern half of the United States, there is no accumulation of practical significance.

Laboratory tests were performed to evaluate the importance of volatilization, leaching, chemical decomposition, and biological degradation as possible factors in the disappearance of these substituted urea herbicides from soil.

The extremely low vapor pressure of 3-(*p*-chlorophenyl)-1,1-dimethylurea suggests that volatilization is unlikely to account for the disappearance of more than a small fraction of this compound under most field conditions.

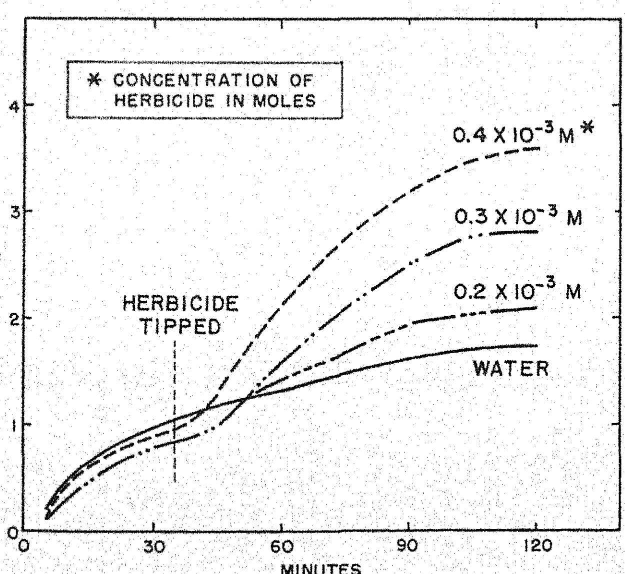

FIG. 24.—Oxidation of 3-(*p*-chlorophenyl)-1,1-dimethylurea by *Pseudomonas* sp. in a Warburg study.

In a lysimeter leaching study carried out under greenhouse conditions, it was demonstrated that some leaching of 3-(*p*-chlorophenyl)-1,1-dimethylurea occurred when large volumes of water, representing extremely high effective rainfall on a porous soil, were passed through soil columns treated pre-emergence with a 10-pound per acre rate. However, under field conditions with application rates of 1 to 2 pounds per acre, removal of 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1- dimethylurea from the soil by percolating water is not regarded as a major factor in disappearance, since essentially all of the chemical recovered upon sampling is present in the 0 to 4-inch layer of soil.

Preliminary results from chemical decomposition studies *in vitro* suggest that hydrolysis or oxidation of the substituted ureas is slow at ordinary temperatures. However, photodecomposition can occur and may be a positive factor in disappearance of the compounds from soil when little rainfall occurs after application and the chemical remains on the soil surface.

It was demonstrated that soil microorganisms play a definite role in the decomposition of these urea herbicides in soils.

(1) In a laboratory study conducted at 80° F.and 60% relative humidity for 22 weeks, there was approximately a 40% loss of both 3-(*p*-chlorophenyl)-1,1-dimethylurea and 3-(3,4-dichlorophenyl)-1,1-dimethylurea when applied to Cecil loamy sand at a concentration of 4 ppm. (1 ppm., 4

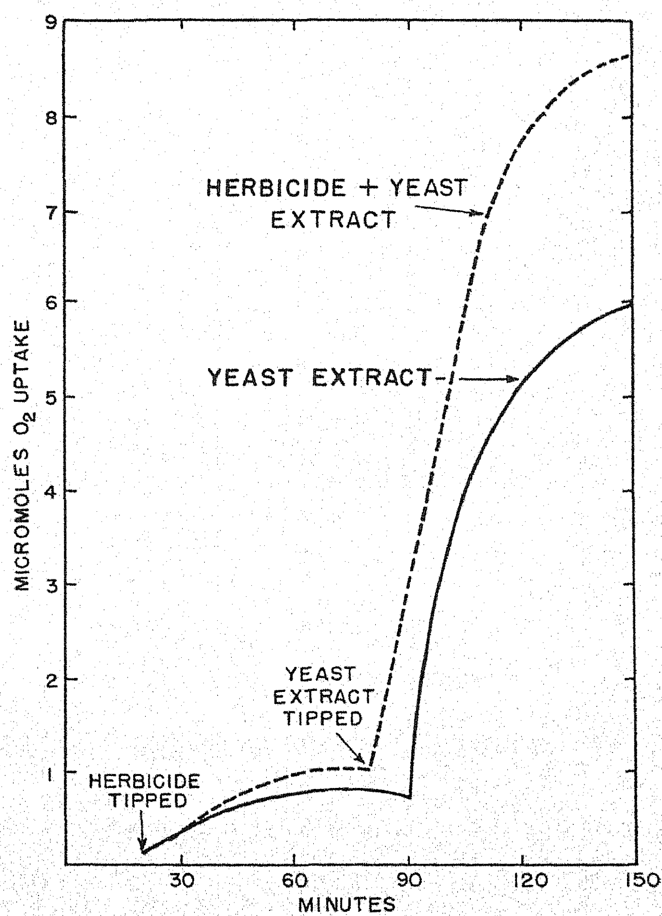

FIG. 25.—Influence of yeast extract on the oxidation of 3-(*p*-chlorophenyl)-1,1-dimethylurea (1 μM ml.) by *Pseudomonas* sp. in a Warburg study.

times) and to Brookston silty clay loam at a concentration of 20 ppm. (5 ppm., 4 times).

(2) When a 2 ppm. concentration of C^{14} methyl-labeled 3-(*p*-chlorophenyl)-1,1-dimethylurea was mixed with a clay loam and incubated at room temperature for 90 days, approximately 10% was decomposed, as measured by $C^{14}O_2$ evolution.

(3) In Warburg studies it was demonstrated that soil microorganisms could use 3-(*p*-chlorophenyl)-1,1-dimethylurea as a sole source of carbon.

On the basis of these laboratory studies, it appears that the disappearance of the substituted urea herbicides from soil under field conditions is due primarily to microbiological decomposition, although the other factors mentioned above may play a role under certain conditions.

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Notes

THE CHEMICAL COMPOSITION OF YELLOW ROCKET (*Barbarea vulgaris*)[1]

FIRST cuttings of hay or hay-crop silage from areas which are infested with yellow rocket, (*Barbarea vulgaris*), frequently contain high percentages of this weed.[2,3] It thus became of interest to determine the value of such materials as measured by chemical composition.

Twenty plants were taken at random from one field of first-year seeding of a mixture of clover, alfalfa, and timothy weekly for a period of 7 weeks from May 5, 1954 to June 21, 1954. Samples were oven dried and ground for analysis. Dates and stages of growth at time of sampling are shown in table 1. Chemical composition and percent dry weight are given in table 2.

These results indicate relatively fair quality roughage value for yellow rocket. The data show yellow rocket to be high in protein and low in crude fiber in the early stages of growth, but a rather rapid reversal occurs as the plant matures. It would thus appear that early cutting is more advantageous from the standpoint of nutrient value.

[1] Rec. for publication Oct. 14, 1954.

[2] Schreiber, M. M., and Fertig, S. N. The effect of various herbicides on the yield and botanical composition of legumes. NEWCC Proc. 8:370. 1954.

[3] Smith, N. J., Fertig, S. N., and Curtis, L. E. 1953 Observations on yellow rocket control in established clover and alfalfa fields. NEWCC Proc. 8:354. 1954.

It has been observed that hay containing a high percentage of yellow rocket is not readily eaten by cows. Most of the yellow rocket is separated out. This is particularly true when

Table 1.—Dates and stages of growth at time of sampling of seven samples of yellow rocket.

Sample No.	Date	Stage of growth
1	May 5, 1954	Early bud stage, no flowers open. Plants 1½ feet tall. Basal leaves still green.
2	May 12, 1954	1/3 flower stage. Plants 1½ to 2 feet tall. Basal leaves starting to yellow.
3	May 20, 1954	Full bloom, no pods formed. Inflorescence starting to elongate.
4	May 27, 1954	½ pod formation. Basal leaves yellowed. Stem leaves yellowing.
5	June 5, 1954	¾ pod formation. Few basal leaves present.
6	June 11, 1954	Full pod stage with few stem leaves present.
7	June 21, 1954	Seed pods still green. Seeds not completely developed.

Table 2.—Chemical composition of seven samples of yellow rocket (dry matter basis).

Sample No.	P*	Ca*	K*	Protein†	Moisture†	Ether extract†	Crude fiber†	Ash†
1	0.53	0.53	3.82	23.4	3.8	——	——	10.1
2	0.48	0.63	3.31	19.7	2.4	2.8	20.0	8.7
3	0.34	0.72	2.19	15.4	3.2	2.5	24.4	7.2
4	0.34	0.88	2.44	12.3	3.3	2.4	29.0	7.2
5	0.31	0.69	2.22	11.7	3.0	1.2	33.8	7.1
6	0.27	1.10	1.81	10.0	1.8	1.2	35.1	6.7
7	0.27	1.03	2.19	9.2	1.9	1.1	35.4	6.6

* Analysis conducted in the Agronomy Department Analytical Laboratory.
† Analysis conducted in the Animal Nutrition Analytical Laboratory.

the first cutting is late and the weed is more mature. Thus the over-all feeding value of the hay is greatly reduced.

On the other hand, the first cutting of hay crop silage with a high percentage of yellow rocket is generally consumed. Also, when the first cutting is taken for hay crop silage the protein value is, of course, higher since the crop is at an earlier stage of growth. Thus the true value of forage containing a high percentage of yellow rocket is realized more as hay-crop silage than as hay.—MARVIN M. SCHREIBER *and* STANFORD N. FERTIG, *Agronomy Department, Cornell University, Ithaca, N. Y.*

AN ATTACHMENT FOR A FIELD CHOPPER FOR MEASURING THE AREA HARVESTED[1]

FEEDING studies involving the use of fresh-cut forage often require an accurate measure of the area chopped as well as the amount of forage harvested. Mechanical counters mounted in wheel rims have been available for some time for measuring wheel revolutions from which area may be calculated.

Counting devices mounted on auxiliary wheels are advantageous on field choppers because the count can be stopped on turns, around the ends of fields and wherever the chopper is not cutting. Extra wheels running on the ground have sometimes been used. These may be raised and lowered with ropes and pulleys controlled from the tractor seat.

The counting device shown in the photograph and used in "greenlot" feeding experiments consists of a mechanical counter on a bicycle wheel rim which has been mounted on a reel assembly from a grain combine and attached to the chopper. The wheel is raised and lowered by a rope from the tractor seat onto one of the chopper wheels. The counter wheel "brake" prevents the wheel from oscillating as it is raised. (Without a brake the counter may oscillate enough to record 2 or 3 extra counts.) This brake was made from a grain check-spring from a discarded grain binder and rigidly supported as shown. There is less chance of the counter wheel getting fouled with this arrangement than with the wheel on the ground.

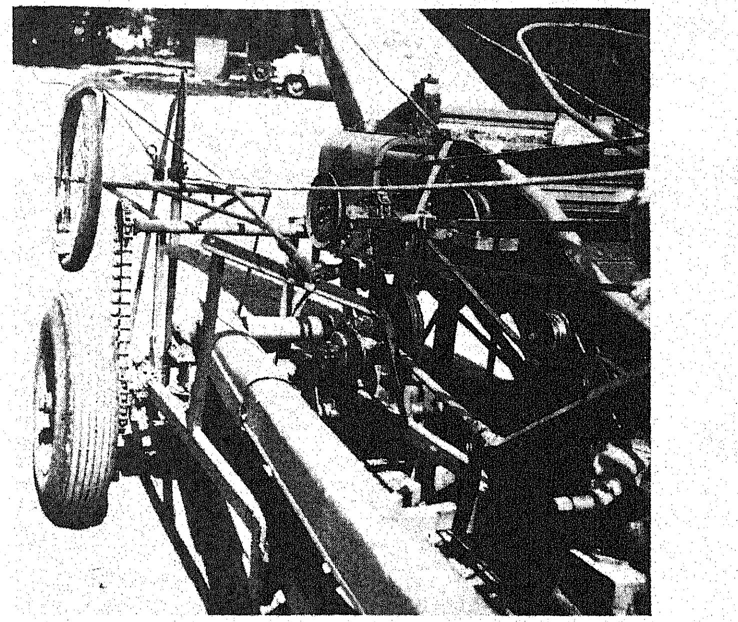

FIG. 1.—Counting device used in "greenlot" feeding experiments.

This adaptation was developed by L. S. Cutter, superintendent of the Soil Conservation Experimental Farm at Shenandoah, Iowa.—J. M. SCHOLL, *Associate Professor Farm Crops, Agronomy Department, Iowa Agricultural Experiment Station.*

[1] Contribution from the Iowa Agricultural Experiment Station, Ames, Iowa. Journal Paper No. J-2591, Project 1016. Rec. for publication Oct. 11, 1954.

Book Reviews

ELECTROMETRIC pH DETERMINATIONS

By R. G. Bates, John Wiley & Sons, Inc., New York. 331 pp. 1954. $7.50.

In the preface the author states, "The acute observer is likely to be appalled at the widespread misunderstanding of the principles of pH determinations." The author proceeds in the book to discuss the assumptions, limitations, and technique of pH measurement with the hope of providing a clear understanding of an electrometric pH measurement. The author sets forth two objectives: first, to present the theoretical and experimental basis for a practical electrometric scale of acidity, and second, to prepare a practical handbook of the many experimental aspects for the assistance of those who measure pH. The author has achieved both of his objectives in an excellent manner.

The scope of the work is indicated by the chapter titles: fundamental principles and conventions; definitions of pH scales; liquid-junction potentials and ionic activities; establishment of pH standards; buffered solutions; quantitative aspects of acidity and basicity in nonaqueous solutions; cell electrodes and techniques; properties of glass electrodes; measurement of electromotive force with a pH meter (a detailed discussion of the instrumentation); automatic pH control.

Six tables are given in the appendix covering values of 2.30259 RT/F from 0 to 100° C., ion product of water from 0 to 60° C.; vapor pressure water from 0 to 100° C., constants of the Debye–Hückel theory from 0 to 100° C., dielectric constants of pure liquids, and approximate pH of some common reagent solutions near room temperature. Parts of the book were reviewed by several of the leading workers in the field of solution chemistry. This authoritative work will be wanted by each soil chemist as a part of his personal library.—M. L. JACKSON.

THE LOST VILLAGES OF ENGLAND

By Maurice Beresford. New York. The Philosophical Library. 455 pp. 1954. $12.00.

Tudor England had its share of farm problems, the vestigial remains of which are the subject of this fascinating book. It is interesting to see the similarity between some of today's basic farm problems and those of 15th and 16th century England. Although for a variety of reasons, numerous farm villages thrived and disappeared from the Norman conquest until the early 15th century, the period from roughly 1440 to 1520 was marked not only by the great number which were depopulated in the English Midlands, but also by the fact that most of the depopulation resulted from a landlord's decision to convert from cereal crops to grass. By the early 15th century, numerous factors had disturbed a long-time balance between row crops and pasture in favor of the latter. Owners could make more money on grass and

sheep than they could on grain and cows. The conversions destroyed more than 500 villages, leaving only a shepherd or two where several families had formerly lived, tilling the fields. By the middle of the 16th century, the two types of farming were again in balance, due in part to antidepopulation statutes which took some of the profit out of the practice. But the lost villages did not revive.

With the aid of aerial photographs, extensive documentary research, and the sweat of pick and shovel digging, the author has located the sites of numerous lost villages, and gives us an excellent picture of their original extent. The causes and the nature of depopulation are as thoroughly covered as the extant documents of the era permit. Descriptions of the homes and villages are of unusual interest.

The book is an excellent contribution to the economic history of England. It is of great value to farm economics students in this country to whom the parallels in today's farm problems are obvious though different in degree.

AGRICULTURE—A NEW APPROACH

By P. H. Hainsworth. Faber and Faber. 24 Russell Square. London. 1954. 21 shillings.

This book may well be called a "closely reasoned appraisal of organic methods of farming." As a market gardener who has used both organic—or natural, fertilizer, and chemicals—or artificials, Mr. Hainsworth is not propagandizing any fads or fancy. His success in getting better nutrition for crops through studied use of organic fertility is interpreted as far as possible in terms of the scientific principles involved, especially the manageable ones.

Among the separate newer approaches cited, there are: *(a)* the use of the organic fertilizers with their carbon-nitrogen ratios in proper balance to serve in the nutrition of the soil microbes so they are non-competitors with the crops for the inorganic fertility; *(b)* the practice of composting highly woody wastes as help in bringing about a narrower carbon-nitrogen ratio in the organic matter above the soil before it can serve promptly as a fertilizer within the soil; *(c)* higher "resistance" to diseases and more complete "protection" against insect damage to crops in consequence of organic manuring of the soil growing them; *(d)* larger seed yields, of clovers especially, through fertilizing highly with organic manures and, maintenance of higher levels of organic matter in the soil; *(e)* escape from the disturbed inorganic nutrition of the plants by the excess and imbalance of monovalent elements as illustrated by potassium not only in artificials but even from organic manuring.

Some non-thinking faddists might be content to say "Organic manuring is efficient because it is natural." The author, however, is not of that cult. He is a plant physiologist and student of soil, putting the best of science under the organic aspects of plant creation which constitute more of agriculture in practice than we have yet suggested.

"Let us study things as they are and not what we have made them. Let us question our beliefs to see whether they really fit the facts. If they don't, cast them out." That is much of the philosophy in which Mr. P. H. Hainsworth presents organic farming in a good clear style and well worthwhile reading.—W. A. Albrecht.

ELEMENTS OF SOIL CONSERVATION, 2ND EDITION

By Hugh Hammond Bennett. New York. McGraw–Hill Book Co., Inc. 358 pp. 1955. $3.96.

As chief of the USDA Soil Conservation Service from 1935 to 1951, the author and his approach to the subject of soil conservation need no introduction to agronomists. This current revision brings the original 1947 volume up to date. Intended for classroom use, the book surveys the numerous aspects of soil erosion, its control and prevention. There are 23 main chapters. Nine of them deal with such general aspects as extent and effects of erosion, how it takes place, rates of erosion and runoff, climate and erosion, rainfall penetration, a national soil conservation program, and planning for soil and water conservation. Thirteen deal with use of vegetation, contouring, terracing, channels and outlets, gully control, stream banks, water spreading, wildlife, farm ponds, stubble mulching, farm drainage, farm irrigation, planting trees and shrubs, and upstream flood control.

The student can get a stimulating introduction to the broad field of soil conservation and can become familiar with the numerous practical problems and applications of conservation from this book. It is an excellent reference book for a farmer's bookshelf, and would give much-needed material to the non-farm nontechnical readers with a desire to be well-informed on one of the country's most important problems.

CONSERVING NATURAL RESOURCES

By Shirley W. Allen. New York. McGraw Hill Book Co., Inc. 347 pp. 1955. $5.50.

The author states that the motive for this book was his desire to see a unified presentation of the broad subject, keeping constantly in mind the following essentials of sound resource conservation: use with minimum waste, increasing productivity where possible and desirable, and equitable distribution of resources now and for the future. With these three broad essential aims in view, his discussion covers the following topics: inexhaustible natural resources—air and water; replaceable and maintainable resources—water in place, soil, land in its spatial sense, forests, forage and cover plants, wild-animal life, and human power; and irreplaceable resources—minerals, metals, mineral fuels, etc., and the land in its natural condition.

The summary chapter on soil conservation is well done with a well balanced discussion between the problems of physical erosion and those of maintaining soil fertility. The problems of adequate flood control are clearly and fairly analyzed. For the general reader, the short history of public policy on conservation should be of great interest, as it traces the development of public laws relating to land and resources from the Homestead Act of 1862 up to the problems created by World War II and the post-war years. His closing chapter on "Human Powers as Natural Resources" deserves special commendation.

The book is written as a college text, and its emphasis throughout on the social responsibilities of "owners" of natural resources should serve well to instill desirable attitudes early in the minds of students who will be guided into positions of influence in public and private bodies. Dr. Allen is professor emeritus in the forestry department of the University of Michigan School of Natural Resources.

BETWEEN US AND HUNGER

By C. Mayadas. London, Oxford University Press. 157 pp. 1954. $2.65.

The author predicts that 218 million people in India will face starvation by 1971. The urgent task implied in the title is to increase the productivity of Indian agriculture to avert that catastrophe. To reflect on the food and population situation in India is disturbing enough to thoughtful observers outside the country. The solution to the problem seems all the more urgent when one reads a discussion of it by a native Indian.

Dr. Mayadas has examined the food situation in India and points out its causes and the weaknesses which underlie it. He considers the prospects of overcoming the acute food shortage which is aggravated each year by an additional 5 million mouths to feed.

To Americans alerted to the need for greater soil conservation, the Indian situation is most easily understood when one is told that 123 million acres of the 400 million tillable acres of India are being eroded by primitive methods of farming. As general short-term measures to help correct the situation, the author urges consolidation of land holdings, conservation of water supplies, mechanization of farming, and some social and administrative reorganization to promote the widespread adoption of the particular practices called for in these general measures. He believes that these can successfully stave off starvation. There is no discussion, however, of the desirability or means of limiting the rate of population increase.

This is a valuable book for any student of agriculture. It is written forcefully and clearly, and will add greatly to our understanding of the economic and political forces at play in that part of the world.

MENTION

Report on the investigation of leaching of a sanitary landfill. Pub. 10, State Water Pollution Control Board, Sacramento, Calif. 1954.

List of References to Boron Literature, reviewed October 1953 to December 1953. Library, American Potash Institute. Washington, D. C. Dec., 1954.

Technical manual of microbiological analysis of soil (in French) by J. Pochon. Monographs of the Pasteur Institute. Masson and Co., Paris. 1954.

Agronomic Affairs

MEETINGS

Mar. 6–12, consecutive meetings, American Society of Photogrammetry, March 6–9; American Congress of Surveying and Mapping, March 9–12, Shoreham Hotel, Washington, D. C.

April 27–29, Arid Lands Symposium (AAAS) Albuquerque, N. Mex.

June 27–29, North Central Section, A.S.A., Iowa State College, Ames.

Aug. 1–6, 3rd International Congress of Biochemistry, Brussells, Belgium.

Aug. 15–19, American Society of Agronomy and Soil Science Society of America, University of California College of Agriculture, Davis.

RESOLUTIONS ADOPTED AT THE 1954 SOCIETY ANNUAL MEETING

The following report of the Committee on Resolutions and Necrology was presented at the 46th annual meeting of the American Society of Agronomy, Nov. 10, 1954, at St. Paul, Minn.

EXPRESSION OF APPRECIATION

The societies hereby express their gratitude to the individuals and organizations in Minnesota who have helped make the 1954 meetings at St. Paul a success. We are especially indebted to various members of the staff of the University of Minnesota for their part in arranging for meeting places, in assembling and operating projection equipment, and in making plans for the ladies' program. Thanks are due the following organizations for their generous support of various activities during the week: Green Giant Canning Co., Land O' Lakes Inc., the American Seed Trade Assn., the Minnesota Farm Bureau Service Co., and Northrup King and Co. Our thanks are also extended to the commercial exhibitors who provided interesting displays and important financial support for our meeting. The St. Paul Chamber of Commerce and the staffs of the St. Paul, Lowry, Ryan, and St. Francis hotels are to be commended for their cooperation in helping to make the meetings come off smoothly. Let us express our appreciation in applause.

MEMORIAL RESOLUTIONS

It is our custom at this occasion to give recognition to members of the American Society of Agronomy who have died since the last annual meeting. Among these men were outstanding leaders in their chosen fields of teaching, extension, research, and administration. In numerous ways they have made important contributions to the advancement of soil and plant sciences and to the development of improved agronomic practices. Their passing is a distinct loss to the society and to their families, friends, and associates. Biographical sketches have been prepared as memorials to the following deceased members:

WALTER N. BANGHAM, geneticist, Goodyear Tire and Rubber Co., died May 5, 1954 at the age of 51.

BURTON B. BAYLES, cereal breeder, Division of Cereal Crops and Diseases, U.S.D.A., died April 21, 1954 at the age of 54.

MARTIN AVERILL BELL, Assistant Director, Montana Agricultural Experiment Station, died Feb. 21, 1954 at the age of 56.

L. L. COMPTON, Professor of Agronomy, Kansas State College, died Jan. 28, 1954 at the age of 49.

FRANKLIN L. DAVIS, Professor of Soil Chemistry, Alabama Polytechnic Institute, died Sept. 6, 1954 at the age of 52.

ORA S. FISHER, Retired director of USDA Extension Program in Agronomy, died Nov. 3, 1954.

WOODROW W. MARCHBANKS, Assistant Professor of Agronomy, Mississippi State College, died Oct. 27, 1954 at the age of 40.

ARTHUR G. MCCALL, retired soil scientist, Soil Conservation Service, died Oct. 19, 1954.

DAVID ALEXANDER SAVAGE, Superintendent, U. S. Southern Great Plains Field Station, died April 3, 1954 at the age of 53.

LEWIS J. STADLER, geneticist, USDA and University of Missouri, died May 12, 1954 at the age of 58.

O. S. AAMODT
J. E. ADAMS
J. W. LAMBERT
L. G. MONTHEY
R. M. HAGAN, *chairman*

WALTER N. BANGHAM

WALTER N. BANGHAM, geneticist for 17 years with the Goodyear Tire and Rubber Co., died May 5, 1954, following an emergency operation in Indonesia where he was engaged in plantation research. He is survived by his widow, Catherine Masters Bangham.

Mr. Bangham was a leading authority in the field of genetics. In addition to serving the Goodyear Co., for many years he was engaged as a consultant for several other firms and the Rockefeller Foundation.

He was born in Wilmington, Ohio, on May 4, 1903. He received his bachelor's degree from Ohio State University in 1926, and a master's degree from Harvard University in 1929.

During the early part of his career, Mr. Bangham was associated with the Firestone Rubber Plantation Co. as a botanist. In later years he devoted himself to serving agriculture in Latin American countries. At the time of his death he was a member of the board of directors of the Inter-American Institute of Agricultural sciences in Costa Rica.

During World War II Mr. Bangham was associated with the office of Inter-American affairs. In 1945 he served as a delegate to the Conference of Inter-American Agriculture in Caracas, Venezuela. The services he rendered during the war years, while a member of the Coordination Commititee for Costa Rica, were gratefully acknowledged by the office of the Coordinator of Inter-American Affairs.

Mr. Bangham was a member of the Harvard Club of New Canaan, Conn., the Explorer's Club of New York City, the Tokeneke Club of Darien, Conn., the Men's Garden Clubs of New York and Fairfield, and the American Agricultural Editor's Association.

BURTON B. BAYLES

BURTON B. BAYLES died suddenly on April 21, 1954, at Beirut, Lebanon, while enroute to Damascus, Syria, to attend the Third FAO Wheat and Barley Breeding Conference. Dr. Bayles was born near Manhattan, Kans., on Jan. 10, 1900. He began working in the Cereal Breeding Nursery as a youth while a student at Kansas State College, from which he continued such duties at Kansas State College until his graduation with a B.S. degree in 1922. He then joined the former Division of Cereal Crops and Diseases of the Bureau of Plant Industry and served at Hays, Kans., 1922–23; at Moro, Oregon, 1923–27; Moccasin, Mont., 1928–30; and at Washington, D. C., and Beltsville, Md., thereafter. He received his M.S. degree at Kansas State College in 1926 and his Ph.D. at the University of Wisconsin in 1936.

From 1930–35 he directed wheat research in the Far West and Intermountain states, and from 1936 until his death he had charge of wheat research in the Eastern States. He also served as Assistant Chief of his Division from 1941 to 1946, and directed wheat-quality research thereafter. In recent years Dr. Bayles took an active part in helping to organize wheat improvement in Mexico, South America, and the Near East, and he traveled extensively in those areas.

Dr. Bayles will be best remembered for his work in the classification, physiology and breeding of wheat varieties. He was the author of many scientific papers and contributed articles on wheat and cereals in various encyclopedias. He bred the Rex variety that formerly was widely grown in Oregon, and he tested and released the very hardy Yogo winter wheat variety in Montana.

Dr. Bayles was a veteran of World War I and a Fellow of the American Society of Agronomy. He is survived by his wife Clara, two sons, a daughter, and grandchildren.

MARTIN AVERILL BELL

MARTIN AVERILL BELL, assistant director of the Montana Agricultural Experiment Station, died at his home in Bozeman, Mont., on Feb. 21, 1954. He is survived by his widow, Mrs. Emma Oman Bell, a daughter, Elizabeth, and two sons, Richard O. and William A.

Born in Maryland in 1898, he came to Montana with his parents in 1911 and they homesteaded in Wibaux County. He was graduated from Wibaux High School in 1917 and immediately enlisted in the United States Navy where he served 2½ years during World War I. After an honorable discharge from the Navy, he came directly to Montana State College where he earned the Bachelor of Science degree in agronomy in 1924. From 1924

to 1927 he was employed as Assistant Agronomist at the North Montana Branch Experiment Station at Havre. During 1927 to 1928 he engaged in graduate work at Iowa State College from which he received the Master of Science degree in Agronomy.

Returning to Montana in 1928 he was associated with the North Montana Branch Station as agronomist and superintendent until 1939. In that year he was made superintendent of the Woodward Field Station at Woodward, Okla., in which position he served untitl 1946. In that year he again returned to Montana as superintendent of the North Montana Branch Station. Three years later he became assistant director of the Montana Agricultural Experiment Station. From that time until his death he ably served as assistant director and as acting director for a period of 14 months.

Mr. Bell's studies centered on the climate of the Northern Great Plains and the agricultural adaptations which are needed in this area. His Bulletin No. 336 of the Montana Station entitled, "The Effect of Tillage Methods, Crop Sequence, and Date of Seeding upon the Yield and Quality of Cereals and Other Crops Grown under Dry Land Conditions in North Central Montana," has become an important and well-known writing in the agronomic literature of the Northern Great Plains. His work and association with Montana agriculture was fortunate. Only time will bring full recognition to his work.

L. L. COMPTON

L. L. Compton, professor of agronomy at Kansas State College and secretary-treasurer of the Kansas Crop Improvement Association, passed away in Manhattan on Jan. 28, 1954. His wife and a son and daughter, all at home, survive.

Mr. Compton was born April 21, 1905, at Mankato, Kans. He became agricultural extension agent in Butler county after receiving a B.S. degree in agriculture from Kansas State College in 1930. Six years later he became extension specialist in crops and soils at Kansas State College. While thus employed, Mr. Compton completed work on a M.S. degree in agronomy and received this degree from Kansas State College in 1940. From 1947 until his death he served as Kansas Crop Improvement Association secretary.

L. L. Compton was actively interested in school, church, and civic affairs. He was a member of Alpha Zeta, Sigma Xi, Phi Kappa Phi, Gamma Sigma Delta, and Epsilon Sigma Phi. Professionally he was identified with the American Society of Agronomy and the American Association for the Advancement of Science. At the time of his death Mr. Compton was serving as a member of the board of trustees of the First Methodist Church in Manhattan. He was elected chairman of the Seed Production and Technology Division of the American Society of Agronomy meetings for 1954.

In 24 years of service to Kansas agriculture, L. L. Compton earned the respect and admiration of all who knew him. He was primarily interested in crop production problems and became an authority on matters varying from soil and water management to the use and production of pure seed of improved varieties. His contributions to agriculture along these lines were many, and his sound advice on agricultural matters will be missed by his associates. Firm and sincere convictions made Mr. Compton an inspirational leader and friend.

FRANKLIN L. DAVIS

Franklin Louis Davis, professor and soil chemist of the Alabama Polytechnic Institute, died at his home in Auburn, Sept. 6, 1954. He is survived by his widow, Mary A. Davis, and two sons, Franklin L. Davis, Jr., and Edward Davis.

Dr. Davis was born in Cabool, Mo., Feb. 19, 1902. He received his B.S., M.A., and Ph.D. degrees from the University of Missouri, completing his doctoral work in 1936.

During his professional career he had served as agricultural teacher at the School of the Ozarks, Research Assistant at University of Missouri, assistant professor of soils at North Carolina State College, assistant soil chemist with Alabama Agricultural Experiment Station, and associate soil technologist with the Louisiana Agricultural Experiment Station. He returned to Auburn in 1947 to teach and conduct research in soil chemistry. He was appointed a member of the graduate faculty in 1953.

In 1929 Franklin Davis attended the 2nd International Congress of Soil Science in Moscow as an honorary delegate from North Carolina State College. He was a member of the American Society of Agronomy and served as chairman of the Soil Chemistry Division of the Soil Science Society of America in 1948. He was a fellow of the American Association for Advancement of Science and a member of Sigma Xi and Gamma Sigma Delta, honorary fraternities.

At the time of his death, he was conducting research on lime and its effects on the availability of plant nutrients to various crops. Among his recent contributions was the discovery of the effect of lime on the volatility of the dinitros used as weed killers. During his research career he published numerous scientific papers on soil phosphorus, the chemical properties of soil profiles, sources of liming materials, rotations of crops, lime requirement methods and the mineral nutrition of plants.

ORA S. FISHER

Ora S. Fisher, for many years head of USDA Extension program in agronomy, died Nov. 5, 1954 in Washington, D. C.

A native of Washburn, Ill., he was graduated from the University of Illinois where he directed the seed improvement program for several years. He joined the U. S. Department of Agriculture in 1916 and helped to develop its extension program in agronomy and seed improvement. He continued in this work until his retirement in 1948. He was one of the organizers of the International Crop Improvement Association.

WOODROW W. MARCHBANKS

Woodrow W. Marchbanks, assistant agronomist and professor at Mississippi State College, died at the Maxwell Air Force Base Hospital, Montgomery, Ala., on Oct. 27, 1954. Dr. Marchbanks became afflicted with bleeding gums on Sept. 16 and a few days thereafter he was flown to the hospital at Montgomery, Ala., where it was discovered that he had aplastic anemia. He is survived by his widow Mrs. Armor Lee Marchbanks, formerly of Canyon, Texas, and two sons, Albert Joe, 6, and Si Clinton 4.

Dr. Marchbanks was born in Childress, Texas, Sept. 30, 1914. He received his B.S. degree in 1938 from West Texas State Teachers College. In 1947, he obtained a B.S. degree in Agronomy Crops from Texas A & M College and an M.S. degree in the same field from Texas A & M College in 1949.

He served in the Navy, 1942–46, with the rank of lieutenant. He took part in the Guadalcanal, the New Guinea and the Admiralty Islands Campaigns. He was wounded in action and received a Presidential Unit citation.

His professional career began with his employment as an instructor in agronomy at Mississippi State College in 1949 and in 1950 he resigned to accept a graduate research assistantship to enable him to pursue graduate study, leading to the doctorate in agronomy. He received the Ph.D. degree from Mississippi State College in January, 1953, the first such degree ever granted by Mississippi State College. He joined the staff of Mississippi State College as assistant agronomist and assistant professor in June, 1952, and since that date he had been in charge of instruction in the 4-year seed training program, the only 4-year seed training program in the United States. Also, he had been in charge of the agronomic phases of seed research in the Regional Seed Research Laboratory at State College. He helped conduct several annual seedsmen's short courses which had been attended by upwards of 200 seedsmen from 25 states.

Dr. Marchbanks belonged to Phi Kappa Phi Honorary Scholastic Society, the American Society of Agronomy, and the Association of Southern Agricultural Workers. He was a Methodist and a Mason. He wrote a monthly column entitled "Seedsmen's Clinic" for the Seedmen's Digest, published in San Antonio, Texas.

ARTHUR G. McCALL

Arthur G. McCall, well known soil scientist who served as a consultant with the Soil Conservation Service, U.S.D.A., since his retirement in 1944, died Oct. 19, 1954, in Olney, Md. He is survived by a son, Herbert F. McCall, three daughters, Mrs. Betty Lumley, Mrs. Dorothy Compher and Mrs. Harriett Gormley; and three brothers, C. H. McCall, E. A. McCall and Otto McCall. His wife was the late Harriett Flower McCall.

A native of Ohio, he received his bachelor and master of science degrees from Ohio State University and a Ph.D. degree from Johns Hopkins University in 1916.

Dr. McCall was associated with the U. S. Bureau of Soils from 1901 to 1904 at which time he became assistant professor of agronomy at Ohio State University. In 1916 he became pro-

fessor of geology and soils at the University of Maryland, serving in this capacity until 1927 except during 1919 when he served as head of the agronomy staff of the American Expeditionary Force stationed at Beaune, France. While there he established an American University in Europe for servicemen. In 1927 he became chief of soil investigations of the U.S.D.A. and was with the Soil Conservation Service from 1936 to his retirement.

Dr. McCall served the American Society of Agronomy well. He was a member of the Committee on Varietal Nomenclature, 1913–1917; the Committee on Fertilizers, 1921; first Vice-President. 1918–1919; second Vice-President, 1925; Assistant Treasurer, 1929–1937; and President of the Society, 1928. He was elected as a Fellow in 1927.

In the 1927 International Congress of Soil Science, he was executive secretary. He was a charter member of Alpha Zeta honorary college fraternity, a member of the Cosmos Club, the First Congregational Church, as well as various scientific groups. Dr. McCall authored a number of soil conservation handbooks.

DAVID ALEXANDER SAVAGE

David Alexander Savage, superintendent of the U. S. Southern Great Plains Field Station, Woodward, Okla., died April 3, 1954. Survivors include his widow, Claire, and one daughter, Mrs. Claire Ellen Furlong.

David Savage was born at Laurel, Mont., on Aug. 12, 1901. After graduating from Montana State College in 1924 he took a position as junior agronomist with the Bureau of Plant Industry until 1927. He was a member of the experiment station staff at Montana State College in 1927 and 1928. He rejoined the Bureau of Plant Industry in 1928 and was stationed at the Fort Hays Experiment Station, Hays, Kans., until 1937 when he became project leader of the Division of Forage Crops and Diseases at the Southern Great Plains Field Station. Mr. Savage was promoted to Senior Agronomist in 1942 and to Superintendent of the Woodward Station in 1948.

D. A. Savage left a well marked trail of major accomplishments in the field of rangeland improvement. He developed methods for reseeding abandoned farm and crop land which have been applied on nearly a million acres in the Southern great plains. He was also instrumental in developing brush control practices for range improvement that have been used on well over one million acres of sagebrush-infested ranges. He was a recognized authority and a noted author in the fields of forage crops and range improvement.

In 1946 Mr. Savage was detailed to Alaska by the U.S.D.A. to investigate the potentialities of that area for range livestock. He was a member of a technical assistance group sponsored by the International Bank of the United Nations and FAO to Uruguay in 1950, and in 1952 he was assigned as leader and a range management specialist on a FAO mission to Mexico. This assignment was conducted at the request of stockmen and the government of Mexico to advise and assist in the development, planning and executing of a program for increasing the productivity of grazing lands. Mr. Savage resumed his position as superintendent of the Southern Great Plains Field Station in November 1953.

Mr. Savage was a charter member of the American Society of Range Management and served as President in 1950.

LEWIS J. STADLER

Lewis J. Stadler, international authority on mutation genetics, died in St. Louis, Mo., on May 12, 1954. Dr. Stadler was born at St. Louis, July 6, 1896. He attended the University of Missouri for 2 years, then transferred to the University of Florida where he received his B.S. degree in agriculture in 1917. He was Research Fellow in Cereal Crops Improvement at the University of Missouri 1917–18, receiving his A.M. in agronomy and plant breeding in 1918. In 1919 he studied at Cornell University, and returned to the University of Missouri where he completed his doctorate in 1922. In 1925–26 he was National Research Fellow in Biology, doing post-doctorate work in genetics at Cornell and Harvard Universities. He served as visiting professor at the California Institute of Technology in 1940 and at Yale in 1950. From June 1917 until his death in 1954, except for the brief periods mentioned above, Dr. Stadler was located at Columbia, Mo., where he was employed jointly by the U.S.D.A. and the University of Missouri. He served as a second lieutenant in World War I and was a member of the Scientific Advisory Committee of Selective Service during World War II.

Dr. Stadler's most outstanding scientific contributions have been in the field of mutation genetics. Along with Muller he was a pioneer investigator of the genteic effects induced by x-ray treatments. Later his experiments were enlarged to include the effects induced by treatments with ultra-violet radiation. His critical analyses of the genetic effects induced by x-rays led him to conclude that all of the x-ray induced mutations in maize are extragenic in origin and differ fundamentally from those occurring spontaneously. His brilliant experiments on mutations and mutation processes have done much to advance our knowledge of the organization of the gene.

Dr. Stadler was a member of the National Academy of Science, the American Philosophical Society, the American Academy of Arts and Science, The American Society of Agronomy, the Genetics Society of America, the Botanical Society of America and other scientific societies. He was a member of the editorial boards of Experimental Biology Monographs, Advances in Genetics and the American Naturalist. Among the elective offices he held were those of president af the Genetics Society of America and national president of Sigma Xi.

A great scientist with a friendly spirit has departed. He will long be remembered for his general devotion to scientific research and for the high quality and logical analysis of his own experiments.

STANDING COMMITTEES, 1955, AMERICAN SOCIETY OF AGRONOMY

PUBLICATION OF RESEARCH PAPERS

L. G. Monthey	S. P. Swenson
R. J. Muckenhirn	C. F. Simmons
R. D. Lewis	D. H. Sieling

G. M. Browning, *chairman*

PUBLICATION NEEDS OF A.S.A.

A.S.A.	*Soils*	*Crops*
W. M. Meyers, *chairman*	L. A. Richards	D. F. Beard
M. L. Peterson	H. E. Myers	T. H. Rogers
H. M. Tysdal	A. G. Norman	H. B. Sprague

RELATIONSHIP WITH THE SEED INDUSTRY

C. S. Garrison, *chairman*	J. R. Holbert
D. F. Beard	J. C. Lowery
E. N. Fergus	H. B. Musser
F. V. Grau	F. G. Parsons

NOMINATING COMMITTEE

G. O. Baker	R. R. Robinson
W. R. Paden	G. E. Smith

H. E. Myers, *chairman*

LOCATION OF MEETINGS

S. R. Aldrich	H. T. Rogers
I. M. Atkins	F. W. Slife
H. B. Cheney	R. S. Whitney

Harold E. Jones, *chairman*

NOMINATION OF FELLOWS

L. T. Alexander	C. D. Jeffries
R. E. Blaser	L. A. Richards
F. V. Burcalow	F. B. Smith
B. A. Brown	N. J. Volk

C. J. Willard, *chairman*

STANDING COMMITTEES, 1955, CROP SCIENCE DIVISIONS, AMERICAN SOCIETY OF AGRONOMY

VARIETAL STANDARDIZATION AND REGISTRATION

F. N. Briggs	I. J. Johnson
J. O. Culbertson	R. E. Karper
L. F. Graber	H. C. Murphy
M. A. Hein	J. F. O'Kelley
E. A. Hollowell	T. M. Stevenson

M. G. Weiss, *chairman*

CROP TERMINOLOGY

C. J. Willard C. P. Wilsie
G. H. Ahlgren, *chairman*

TURFGRASS

Kling Anderson	A. G. Law
W. H. Daniel	H. B. Musser
J. A. DeFrance	O. J. Noer
R. E. Engel	G. C. Nutter
M. H. Ferguson	H. H. Rampton
R. M. Hagan	V. T. Stoutemyer
C. K. Hallowell	J. R. Watson
J. C. Harper	F. V. Grau, *chairman*

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G. W. Burton L. F. Graber
D. W. Robertson, *chairman*

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The presidents reported briefly on the program in each region for the past year and the progress made. Strengthening and expanding the regional program, and possible benefits therefrom, was discussed. It is believed that one of these benefits would be the encouraging of the development of young scientists through their participation in the regional program. Strong regional programs will permit the society to render greater member service to its members. Expansion of regional programs could also help stimulate the interest of crop and soil scientists working in related agencies. Through participation in regional activities of ASA by members of other societies, such as the Soil Conservation Society of America, Range Management Society, and regional weed groups, related programs could be coordinated. Regional meetings provide an excellent opportunity for the teachers in agronomy to get together in a program under the auspices of Division XIII, Agronomic Education. Participation of students in the student activities section could also be encouraged.

It was also visualized that regional programs tied in with the program of the membership committees could provide opportunities for stimulating interest in the affairs of the society and soliciting new members. The presidents pledged themselves to support, whenever possible, the membership program through their regional programs in an effort to expand membership and strengthen the Society. They will cooperate closely with the regional membership chairman.

The interest and enthusiasm shown by the regional officers in this meeting demonstrated that much progress has been made during the year and prospects were promising for considerable progress in the year ahead. The North Central Region and the Western Region reported that each had completed the bylaws of its regional organizations during the past year and had submitted them to the executive secretary. Copies of these bylaws will be published in the *Soil Science Society of America Proceedings* and the *Agronomy Journal* as a permanent record and for the information of all concerned.—B. R. Bertramson.

CHARLES W. DOMBY

(Following is a complete obituary notice of the death of Dr. Charles W. Domby which was reported in the January issue.)

Dr. Charles W. Domby, Soil Scientist in the Soil and Water Conservation Research Branch, U.S.D.A., died at his home in Athens, Ga., on Dec. 21, 1954 after an illness of several months.

Dr. Domby was born in Birmingham, Ala., in 1919 and received his B.S.A. degree from Colorado State College in 1940. He was employed by the Soil Conservation Service until 1941 when he was inducted into the United States Army, serving as an officer in the Corps of Engineers until his discharge from military service in 1946. He obtained his M.S. degree from the University of Georgia in 1948 and his Ph.D. degree in Soil Physics from Purdue University in 1953.

He was intensely interested in soil management problems and his scientific contributions included articles on diffusion of air through soil crusts and the effect of freezing on soil aggregation. He was highly respected for his keen scientific mind and loved by all who knew him for his integrity, modesty, generosity, and tolerance.

Dr. Domby is survived by his wife, Barbara Howard Domby, and two sons, Arthur and Charles, Jr.

G. N. HOFFER RETIRES

On Jan. 1, G. N. Hoffer retired as Midwest Manager for the American Potash Institute, a position which he had held since the formation of the Institute in 1935.

Dr. Hoffer is recognized for his research work in plant nutrition, plant physiology, corn breeding, and diagnostic techniques for identifying plant-food deficiencies. He is one of the first to recognize the deterioration in the structure of Midwest soils due to depletion of organic matter and use of heavy machinery. He will remain active as a consultant in his fields of interest and his residence will continue to be in West Lafayette, Ind.

His successor is Werner L. Nelson, who resigned his connections with North Carolina State College last October to work with Dr. Hoffer.

GLENN BURTON IS HONORED

Glenn W. Burton, principal geneticist at the USDA Coastal Plain Experiment Station, Tifton, Ga., received the 1954 "Man of the Year" award of *Progressive Farmer* magazine for service to Southern agriculture. Dr. Burton was recognized for his pioneer work in breeding grasses, particularly Coastal Bermuda which is now one of the most important permanent pasture grasses of the Southeast.

FOA TAKES OVER IOWA TROPICAL RESEARCH CENTER

Iowa State College announced that the U. S. Foreign Operations Administration has taken over the research activities of the Iowa State College–Guatemala Tropical Research Center. Founded by Iowa State College in 1946 with a grant from the Earl E. May Seed Co., Shenandoah, Iowa, the center at Antigua, Guatemala, has been devoted to the study of corn at its place of origin. Supported jointly by the Guatemala ministry of agriculture and the FOA Institute of Inter-American Affairs, the center is now part of the Guatemala experiment station.

COLLEGES PARTICIPATE IN FOREIGN AID

The University of California has announced its participation in a 3-year program of technical assistance to the National Taiwan (Formosa) University. Richard L. Adams, retired professor of farm management, and H. Lee Landerman, former extension agronomist, have left Berkeley for Formosa to start the program.

New Mexico A and M College has furnished a staff of advisors to aid the University of Sind, Pakistan, in setting up a school of agriculture and an experiment station.

FORMER CORNELL DEAN DIES

Liberty Hyde Bailey, at one time director of the Cornell University experiment station, died Dec. 25, 1954 at his home in Ithaca, N. Y., at the age of 96. Dr. Bailey taught horticulture at Cornell from 1888 to 1903 and then became Dean of the College of Agriculture and Director of the station. In 1908 Pres. Theodore Roosevelt appointed him chairman of the Commission on Country Life.

NEW COTTON RESEARCH BUILDING AT CHICKASHA, OKLA.

A new $50,000 storage and processing plant is under construction at the Oklahoma Cotton Research Station at Chickasha. The cost of the new fireproof structure is being shared equally by the Cotton Research Foundation and the Oklahoma experiment station.

MILES IS MISSISSIPPI SECTION PRESIDENT

IVAN E. MILES, Extension Service agronomist, was elected president of the Mississippi Section of the American Society of Agronomy for the coming year at the section meeting Jan. 14. He succeeds Harrison Evans.

WILLIAM L. GILES, superintendent of the Delta Branch Experiment Station, Stoneville, was elected first vice president, in balloting by mail. J. T. Caldwell, Jr., of Jackson was elected second vice president.

C. DALE HOOVER, as head of the Mississippi State College department of agronomy, continues as ex-officio secretary-treasurer of the section.

Dr. Hoover reported that the section's membership increased to 220 by December 31, 1954, and that several new members have been received since then. Approximately 225 county agents, state and federal employees, vocational agriculture teachers, farmers, and commercial representatives attended the meeting.

After a welcome by CLAY LYLE, dean and director of the Agricultural Division of the college, the group heard CHARLES E. KELLOGG of Washington, D. C., PERRIN GRISSOM of Stoneville, W. B. ENNIS of State College, H. S. SAUCIER of Meridian, REX KIMBRIEL of Greenville, J. D. LANCASTER of State College, R. Q. PARKS of Memphis, T. E. ELLIS of Caledonia, and T. M. WALLER of State College.

STUDENT SECTION WILL MEET AT DAVIS, CALIF.

The Student Activities Section of the American Society of Agronomy will hold its 1955 national meeting at Davis, Calif., August 15 to 19, according to an announcement by LESTER H. SCHMIDT, St. Paul, Minn. The section, representing student agronomy clubs at 33 agricultural colleges throughout the U. S., will hold its sessions in conjunction with the national meeting of the American Society of Agronomy. Schmidt is president of the section.

BRADFIELD DIRECTS ROCKEFELLER GROUP IN JAPAN

RICHARD BRADFIELD, head of the Cornell University agronomy department, left the United States Feb. 1 for Manila, Philippine Islands, to begin a year's service as regional director of agriculture in the Far East for the Rockefeller Foundation. He will use Manila as an operational base until June 1 when he expects to move to Tokyo, Japan, with his family. Emphasis in the program which he will direct will be placed primarily on improved rice production.

SOIL CONSERVATION SOCIETY HAS NEW OFFICERS

Officers for the current year, elected by members of the Soil Conservation Society at its November 1954 meeting in Jacksonville, Fla., are as follows:

AUSTIN L. PATRICK, SCS, Arlington, Va., president; EDWARD H. GRAHAM, Falls Church, Va., vice president; ROBERT M. SALTER, Silver Springs, Md., second vice president; HOWARD R. BISSLAND, Winter Park, Fla., treasurer; and FIRMAN E. BEAR, New Brunswick, N. J., CHESTER S. WILSON, St. Paul, Minn., and ELMER L. SAUER, Champaign, Ill., council members.

Society fellowships were conferred upon the following:

FRANK C. EDMINSTER, New Jersey state conservationist; GLENN L. FULLER, San Juan, Puerto Rico, who directed the first national erosion survey in 1934; and DONALD WILLIAMS, SCS administrator.

C. E. RAMSER, USDA research worker of 40 years service, was made an honorary member.

ARMY NEEDS SOILS MAN IN KOREA

The Department of the Army is seeking one soil conservationist for civilian work with the Army in Korea. Single men are preferred, but married men whose families will remain in the U. S. are acceptable.

The soil conservationist Civil Service rating is GS-13 and pays a total annual salary of $10,450. Living quarters and transportation to and from Korea are furnished at no cost to the employee.

At least 5 years of "well-rounded" work experience, 3 years of which must be specialized, are required. To qualify for the grade GS-13, federal employees should have been employed at the GS-12 rating. Highly qualified men from universities and experiment stations may also apply.

Application should be made to the Department of the Army, Office of Civilian Personnel, Overseas Affairs Division, Old Post Office Building, Washington 25, D. C., to the attention of Mrs. J. Nelson.

NEWS ITEMS

W. T. BRIGHAM has been placed in charge of plant pest regulatory and inspection work in Connecticut, succeeding MAX P. ZAPPE who will retire April 1. The latter has been at the Connecticut experiment station since 1914. Mr. Brigham has been a member of the station staff since 1929.

—A—

Balfour, Guthrie and Co., of San Francisco, Calif., announces the appointment of HAROLD FERGUSON as senior assistant to R. E. NEIDIG, vice president of the company's fertilizer and chemical department. Mr. Ferguson was a vice president of the Naco Fertilizer Co.

—A—

JOHN GRAVA has been appointed supervisor of the University of Minnesota soil testing laboratory.

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ROBERT W. EARHART, was recently appointed plant pathologist at the South Carolina Experiment Station, Clemson. He transferred from the Cereal Crops, Section, USDA, at Gainesville, Fla., and is conducting research on the small grain diseases of South Carolina.

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E. J. MITCHELL, of the Flax Development, Flax Institute, Minneapolis, Minn., was named an "Honorary Premier Seed Grower," during the Minnesota Farm and Home Week the week of Jan. 11 at Minneapolis.

—A—

Appointment Jan. 1 of HUBERT H. TUCKER as director and HENRY J. COLEMAN as sales manager of agricultural service in the new Petrochemical department of Standard Oil Co. (Ohio) is announced. Tucker is former president of the Coke Oven Ammonia Research Bureau. The new department is at Lima, Ohio, where a new petrochemical plant will start production in November of anhydrous ammonia, nitrate solutions and urea fertilizers.

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The appointment of WALTER PEEVY to head Agricultural Extension Service work on the maintenance and improvement of soil fertility has been announced by Dean J. G. LEE of the Louisiana State College of Agriculture. In addition to extension work, Dr. Peevy will supervise operation of the university's soil testing laboratory on the campus at Baton Rouge and the mobile laboratory at the Hill Farm Experiment Sub-Station near Homer.

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LYMAN R. AMBURGEY has been appointed extension specialist in soils at the University of Arizona. He is a graduate of the University of Missouri and had been in the Missouri extension service since 1947.

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SEWARD SAND has been appointed to the genetics department at the Connecticut Agricultural Experiment Station to conduct tobacco breeding studies. He received the Ph.D. degree last year from Cornell University and had formerly taught science courses at the Horseheads, N. Y., high school.

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JOHN LETEY Jr. of Glenwood Springs, Colo., has been named the first winner of a $200 award from the National Fertilizer Association for the outstanding senior student in agronomy at Colorado A and M College.

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DEAN F. PETERSON, Jr., head of the department of civil engineering, has been appointed chairman of the Colorado A and M Irrigation Institute.

He will head the council, composed of representatives of various departments on the A and M campus, for a 2-year term. He succeeds Dr. D. W. ROBERTSON, head of the department of agronomy. The Institute is set up to coordinate various aspects of irrigation and promote irrigation and related sciences.

—A—

Since the recent reorganization of the USDA SCS, WAYNE AUSTIN has been attached to the SCS technical staff with headquarters at Oakland, Calif. Since 1950 he had been regional agronomist for the Pacific Region of SCS. His area now covers the seven far-western states, and the territories of Alaska and Hawaii.

CROP TERMINOLOGY

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TURFGRASS

KLING ANDERSON
W. H. DANIEL
J. A. DEFRANCE
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ALTO E. ROYER recently transferred from the Section of Cotton and Other Fiber Crops to the Eastern Soil and Water Management Section, both in the Agricultural Research Service, USDA. He had been stationed at Turrialba, Costa Rica, conducting research on abaca. In his new position he will serve as Soil Scientist at the Southeastern Tidewater Experiment Statiton, Fleming, Georgia.

—A—

W. V. CHANDLER, soil scientist with the Eastern Soil and Water Management Section of the Agricultural Research Service, has been transferred from Raleigh, N. C., to State College, Pa. He will head up a cooperative research project between the ARS and the Pennsylvania Agricultural Experiment Station on deepening of the root zone for crop plants.

—A—

MARLOWE D. THORNE has joined the Eastern Soil and Water Management Section, Agricultural Research Service, as irrigation work project leader. For the past 7 years he has been with the Pineapple Research Institute of Hawaii, his most recent position there being Head of Agronomy Department. He is a native of Utah, and received his undergraduate training at Utah State Agricultural College, and graduate training at Iowa State and Cornell University. In the new position, Dr. Thorne is the technical leader for irrigation research which is conducted cooperatively between ARS and the 31 Eastern States and Puerto Rico. His headquarters are at the Plant Industry Station, Beltsville, Md.

COMMERCIAL NEWS

A new service bulletin on the borate weed killer, Tronabor, has been issued by American Potash & Chemical Corp. in connection with the product's use under asphaltic paving in such cases as airports, highways, parking areas, playgrounds, and other similar applications. Copies can be obtained from the company at 3030 West Sixth Street, Los Angeles 54, Calif.

—A—

A 5,000,000 (12,000 ton) gallon storage system for anhydrous ammonia plus the nation's first river-rail-highway distribution facilities will be placed in operation about March 1, by Mid-South Chemical Co. at Memphis, Tenn.

PERSONNEL SERVICE

The Personnel Service column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of $2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a key number which will be carried for five additional insertions unless a discontinue order is received. Items pertaining to soils positions will be inserted one time in the *Soil Science Society of America Proceedings* unless otherwise specified. The following insertions, published in earlier issues, are still available: **9–2, 11–1, 11–2, 12–1, 1–1.**

POSITIONS OPEN

Experienced corn breeder under 40 for expanding hybrid corn program. Aggressive midwestern agricultural service organization. Salary commensurate with experience. Write giving complete details to: Personnel Department, Cargill, Incorporated, 200 Grain Exchange, Minneapolis 15, Minn. **2–1.**

Applications invited for Assistant Professor of Soil Science, duties commence Sept. 1, 1955. Initial salary: $4,000–$5,000. Cost of living bonus about $300 and normal yearly increment $250. Prefer graduate with Ph.D. degree or equivalent training, who has specialized in soil science.

Duties include research, teaching, soil testing, and extension work. Confirmation of appointment subject to satisfactory completion of probationary period of two to four years.

Address Head of Department of Soil Science, University of Alberta, Edmonton, Alberta, giving details of training and experience, personal information, the names of three referees, and recent photograph.

Closing date: May 1, 1955. **2–2.**

POSITIONS WANTED

Experienced cereal breeder, field and laboratory work, desires position as Technical Assistant. Western location preferred. Full information will be sent on request. **2–3**

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AGRONOMY JOURNAL

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The Contribution of Radiation Genetics to Agriculture[1]

W. Ralph Singleton[2]

RADIATION genetics had its origin in fundamental researches conducted almost 30 years ago. In 1927 and 1928, Dr. H. J. Muller and the late Dr. L. J. Stadler reported the first results of their experiments with X-rays, demonstrating that by this agency it was possible to obtain mutation rates that were much higher than spontaneous rates. As happens so often in new advances in science, these two investigators carried on their researches simultaneously and found essentially similar results. Dr. Muller, then at the University of Texas, now at Indiana University, X-rayed male drosophila while Dr. Stadler, of the United States Department of Agriculture and the University of Missouri, X-rayed seeds of barley and maize.

It should be added parenthetically that X-rays had been used to produce hereditary changes in a living organism, the same fruit fly radiated by Muller *(Drosophila melanogaster)* a number of years before the researches of Muller and Stadler. I came upon a reference to this work quite by accident when I was looking over a biology textbook that my daughter Mary brought home from college. In reading a portion of that textbook under the title "Mutations artificially induced" I ran across this statement: "The first changes in the germ plasm to be produced artificially, propagated by experimental breeding and analyzed as to their nature were obtained in 1920 by the author by the use of X-rays. . . . Several years later evidence of gene mutation by X-ray treament was obtained by other investigators."

The author was James Watt Mavor, then working at Union College in Schenectady, N. Y. The X-raying was done in the Research Laboratory of the General Electric Company at the suggestion of Dr. Willis R. Whitney, director of the General Electric Research Laboratory.

Although this original work did not produce any gene mutations as produced by Muller and Stadler, it was conceived with the idea of "determining if X-rays by affecting the X chromosome could disturb the inheritance of a sex-linked character." The researchers published in 1921 and 1922 in *Science*, and in 1924 in the *Journal of Experimental Zoology*, demonstrated that the inheritance of sex-linked characters was disturbed. In this case the disturbance was due to non-disjunction where two chromosomes failed to separate at meiosis, two going to one cell and none to the other. Non-disjunction in drosophila had been discovered and analyzed by Dr. Calvin Bridges in 1916.

Unfortunately it was not followed through to the production of gene mutations as Muller's research so clearly demonstrated in drosophila several years later, but it is certainly worthy of note from a historical standpoint. Mavor's work was certainly known to both Muller and Stadler. Incidentally, while we are in a reminiscent mood, I should like to point out that in the fall of 1925, when Stadler came to the Bussey Institute of Harvard University to spend a year with Dr. East, he brought with him ears of corn showing mutations produced by X-rays. I saw those ears in the fall of 1925.

However, to keep the record straight, we should like to point out that it was Muller who grasped the full significance of the use of this new tool, X rays, for producing genetic changes on a grand scale in a wide variety of living organisms.

The summary paragraph of Muller's 1927 paper in *Science* reads as follows: "In conclusion, the attention of those working along classical genetic lines may be drawn to the opportunity, afforded them by the use of X-rays, of creating in their chosen organisms a series of artificial races for use in the study of genetic and "phaenogenetic" phenomena. If, as seems likely on general consideration, the effect is common to most organisms, it should be possible to produce, "to order", enough mutations to furnish respectable maps, in their selected species, and by use of the mapped genes to analyze the aberrant chromosome phenomena simultaneously obtained. *Similarly, for the practical breeder, it is hoped that the method will prove useful.*" (Italics mine, W.R.S.)

The method has proved useful. Its usefulness was demonstrated first in Sweden, and not in this country where the original work was done. In the spring of 1928, the late Dr. Herman Nilsson-Ehle, then Director of the Swedish Seed Association at Svalöf and Head of the Genetics Institute of Lund University, was contacted by Gustafsson, one of his students and now at the Forest Research Institute, Stockholm, who proposed to embark on an evolutionary (and also revolutionary) study of agricultural plants by means of X-ray and ultraviolet induced mutations. The thesis was that if nature continually produces mutants of value for the species, it should be possible to produce them experimentally, especially since the mutation rates can be increased so markedly, as had been demonstrated by Muller and Stadler.

Nilsson-Ehle, who had been interested in mutations since the birth of genetics at the turn of the century, immediately grasped the significance of this type of research, not merely for the study of evolution but also for practical plant breeding.

Nilsson-Ehle and Gustafsson found many chlorophyll mutations in barley by the use of X rays. In the middle 1930's, Nilsson-Ehle discovered some mutants characterized by dense heads and very stiff straw. These mutants, called erectoides by Gustafsson, were found to yield equal to the maternal variety, Golden. In 1937, Gustafsson found other

[1] Invitational paper presented before the general meeting, Crops Science Divisions, American Society of Agronomy, St. Paul, Minn., Nov. 9, 1954.

[2] Biology Department, Brookhaven National Laboratory, Upton, N. Y.

erectoides mutants and also a striking variant with distinctly taller straw and 4 days later in maturity.

Erectoides 1 of Gustafsson's experiments and the late tall are of considerable interest. Both arose in connection with chlorophyll mutants, *erectoides 1* along with a *xantha* mutant and the late tall mutant together with an *alboviridis* type. Also, *erectoides 1* is closely linked with a translocation point. In this case there were three drastic effects of radiation: *(1)* a reciprocal translocation, *(2)* a conspicuous change in morphology and *(3)* a chlorophyll mutant. Tested in regular yield trials for 13 years (1940–52) this mutant produced an average of 1.3% more grain at Svalöf than Golden Barley, and tested for 8 years produced 5.1% more straw. In total production it had a 3% superiority. It ripens 1 day later.

Superior Production in Dry Years

The late tall mutant produced, for the same sequence of years, 1.7% more grain and 16% more straw, surpassing the mother strain by 9% of total production. However, it requires 4 days longer growth, distinctly later than Golden Barley. In addition, this mutant shows another property of extreme interest—its ecological requirements are entirely changed, its superior production occurs in dry years; in wet years it is distinctly inferior. Cultivated in eastern Sweden (Uppsala), it surpassed the mother strain by 11% of grain and 19% of yield of straw, making 15% in all. By contrast the *erectoides 1* mutant in the same district yielded somewhat below the mother strain, both as regards yield of grain and straw.

I have given the results of these two mutants in some detail because they represent the first actual accomplishment of the production of superior varieties by the use of radiation. They also stress some points of evolutionary significance. As Gustafsson points out, "We are safe in concluding that by appropriate methods we may induce hereditary changes causing an increase in grain yield, or in yield of vegetative matter, or in both of these properties. Moreover, we can alter the ecological requirments entirely, and in this way create new ecotypes with the same, an abbreviated or a prolonged life cycle. Finally, chromosome breakage and rearrangement do not prevent a complete or even raised production."

Also Dr. James MacKey, one of Gustafsson's associates, has demonstrated radiation induced earliness, greater plumpness and higher yield in oats, and in wheat has produced shorter strawed types, higher yield and resistance to black stem rust. Dr. MacKey is presently a guest investigator in our laboratory.

These examples, taken from Swedish plant breeding, are cited here because they demonstrate so clearly the possibilities and the promise of the use of radiation genetics in plant breeding. They also demonstrate what may be accomplished if there is vision—in this case of Nilsson–Ehle and Gustafsson.

U. S. Slow in Early Research

While this very productive work was going on in Sweden, what was happening in the use of radiation in plant breeding in this country? The answer, unfortunately, is practically nothing. We wonder why. Perhaps we needed a Nilsson–Ehle or a Gustafsson, or perhaps the plant breeders in this country had such a wealth of breeding material that they did not feel the need of new types that could be produced by radiation. This was undoubtedly true for corn, which has a fairly high mutation rate; and plant breeders were busy producing hybrid corn, utilizing the many diverse types of corn already in existence. The time was not ripe for developing new types by use of radiation. This was not true, to the same extent at least, for the cereals. But apparently the cereal breeders either were not impressed with the potentialities of radiation induced mutants or were impressed by the apparent fact that the radiation induced mutants were all harmful, an idea prevalent in the early days of radiation genetics.

At any rate, no serious attempt was made in this country to use radiation as a plant breeding tool until after the war and the arrival of the atomic age when radioisotopes became plentiful and available for research. The research that has demonstrated the usefulness of radiation in plant breeding has for the most part been carried out at laboratories financed by the Atomic Energy Commission or with the aid of grants from the A.E.C.

Regarding the deleterious nature of radiation induced mutants, it can be stated without fear of contradiction that most mutants are of a deleterious nature. The same can be said of spontaneous mutants. But, there is a tremendous difference, between 100% harmful genes and 99.99%. Gustafsson estimates that only 1 in a 1,000 may be useful for plant breeding purposes. But this thousand-to-one shot has paid big dividends in plant breeding. It is to the great credit of Nilsson–Ehle and Gustafsson that they had the vision and the patience to set up experiments, carry them through, and demonstrate that this new tool could be used to produce superior strains of plants. These researches also demonstrate that all new ideas are not confined to any single country or continent. Scientific progress knows no international boundaries.

Mutants Have Stiff Straw

The work begun by Nilsson–Ehle and Gustafsson has been carried on and expanded by Gustafsson and a rather large number of competent colleagues. They have studied a wide variety of plants such as wheat, peas, vetches, potatoes, and find that the same results were obtained in all plants studied. In barley they have observed about 60 erectoides mutants distributed over 16 different loci. Not all of these mutants yield more than the parental strain but they *all* have one property in common, namely, stiffness of straw. This is of economic importance in the prevention of lodging.

There is another property the erectoides mutants have in common. This is their nitrogen preference. The mutants prosper, in relation to their parents, as the nitrogen increases. They change the ecological reaction of the mother strain in one and the same direction and make the organism fit for an extreme nitrogen requirement. Some mutants are even better than the very high-productive variety Bonus with a straw stiffer than the prominent variety Herta, the top variety in this respect. Here is evidently a series of genes which by mutation cause a striking nitrogen preference and make two-row barley even better adapted to human society.

These erectoide mutants which can be termed "nitrogen ecotypes", have a behavior almost opposite to another class of mutants, the bright-green plants, similar, I believe, to glossy seedlings in corn. The bright-green mutants, at least 10 at several loci, suffer from high nitrogen applications. Thus it seems possible that ecotype formation to rich or meagre soil can take place by a single factor mutation. Also, early and late ripening mutants are easily produced, making

the variety adapted to very short or very long growing periods.

At this point it is well to pause and ask ourselves what significance these findings have to agriculture. It seems to me they are of tremendous importance. By using radiation as a tool to induce variability within a species, we can provide the material for selection so that a variety may be tailored to almost any specific set of conditions.

Take corn as an example. Although we have not progressed as far as Gustafsson with his cereals, it seems that most of the types produced in cereals have been produced in maize radiation experiments. By radiation we have induced many short corn plants, some taller, some earlier than the parents and some later. Yield tests have not been made but observations on some of the short types indicate that they may have yield potential. This is true of the spontaneous mutants, reduced internode plants *rd*, the *brachytic*$_2$ plants, also some induced short types. And like the erectoides mutations in barley, they all have stalks less susceptible to lodging than the tall types. We had an adequate test of this on Long Island recently during a visit of those two notorious dames, the hurricanes Carol and Edna, with wind velocities in excess of 100 miles per hour. The short hybrids stood up while most of the other hybrids were laid low.

The work of Gustafsson and colleagues has given us a glimpse of what may be accomplished in the way of breeding with specific objectives in mind. I shall have more to say about this presently when discussing the radiation program at the Brookhaven Laboratory. I think it might be well to discuss now a few of the more outstanding contributions that have been made recently in this country by using radiation.

Atomic Energy Accelerates Research

With the advent of atomic energy, radiation sources became more readily available and several experiments were undertaken with the hope of using radiation to produce better types of plants. One such experiment was that of Dr. Walton C. Gregory who reported to us this afternoon on the progress he has made in the use of X rays in breeding peanuts. In starting the project he had 8 bushels of peanuts X-rayed at the Oak Ridge National Laboratory. (His research program was supported by a grant from the Atomic Energy Commission.) In the X_2 generation of his work he examined 975,000 plant progenies (64 acres). Since mutation rates even under radiation are not high percentagewise, and since beneficial mutations represent only a fraction of a percent of all mutations, it is not hard to see the wisdom of large populations in any radiation experiment. In fact, large populations are necessary for success. Two of the most significant results reported by Gregory were resistance to leaf-spot disease and higher yield.

Dr. K. J. Frey, of Iowa State College, will report to you on Thursday regarding his use of X-rays in developing rust resistant lines of oats as well as strains shorter than the parent variety. This work was done at Michigan State College. Four strains were found which were 1 week earlier in heading and one strain 1 week later than Huron, the parent variety. His results are similar to those of Dr. C. F. Konzak of our laboratory. Dr. Konzak reported his results to a meeting of the Agronomy Society in 1953. He found resistance to rust race 7a, following treatment of oat seeds of the variety Mohawk in the thermal column of the nuclear reactor at the Brookhaven National Laboratory. He also found variants for plant height, maturity and for kernel characteristics.

In addition to using radiation to produce plants resistant to different pathogens, radiation is being used on the pathogens themselves to determine their inherent mutability and to determine more or less the limits for which the plant breeder must breed. Dr. E. C. Stakman reported on this at a hearing on the contribution of atomic energy to agriculture, held in Washington on April 1 of this year. Thus the plant pathologist and the plant breeder working on both the pathogen and the host may get ahead of the mutable rust races by causing the rust to mutate prematurely and then develop strains resistant to those races. The development of disease resistant strains by radiation seems destined to play a major role in plant breeding of the future.

The Brookhaven Program

And now I should like to tell you briefly of some of the radiation experiments at the Brookhaven National Laboratory, especially as they relate to corn. (I am sure you will not be surprised to hear a few words about corn.) Actually our program with corn has been more in the nature of obtaining fundamental information about induced mutations than in developing better strains of corn. In the long run, this seems a wise policy, because we have gained information as to how radiation can be used most effectively in producing mutations, not only in corn but in other plants as well.

Most of the mutation work has been with endosperm characters, because of the ease and certainty of detection and because of the large populations that can be so readily obtained. Considerable time and effort has been devoted to the study of chronic or continuous gamma radiation on mutation rate. This was possible by using a radioactive source of Co^{60}, a good source of highly penetrating gamma rays. The Co^{60} source was set up in the middle of a field and plants grown in circle around it. Thus, we reasoned, it was possible to hit the most sensitive period in the life of the plant, no matter when this sensitive period occurred. There is a fallacy in this reasoning which I shall tell you about presently. Nevertheless, since the field, with modifications, has been in operation for 6 seasons, much has been learned regarding the induction of mutations in growing plants.

First of all we learned that endosperm mutations can be produced in abundance, especially at the higher doses, in excess of 200 r/d. The increase in mutation rate with increased dosage is greater than would be expected if the relationship were linear. Secondly, there was a threshold, somewhere between 20 and 40 r/d, below which there was no increase over the control rate. Incidentally, we learned that the accepted spontaneous mutation rate in maize is about 100 times lower than the actual spontaneous mutation rate. The actual rate is in the order of 5 to 10 per 10^4 gametes instead of per 10^6 gametes as commonly accepted.

Also, through a fortunate accident, we learned that there is a comparatively short time between the induction of the mutation and pollen shedding. We learned this when, in the summer of 1952, due to a mechanical failure of the mechanism that operates the radioactive Co^{60} source, it stayed down in the lead "pig" in the ground for a week with no radiation present in the field. The mutations dropped off rapidly following the accident and returned promptly when the source was put into operation again.

Period of Sensitivity

In the summer of 1953 an experiment was planned to determine accurately the stage in the life of the plant most sensitive to radiation. The criteria used in this study were a number of endosperm mutations and pollen abortion. It should be remarked here that the corn plant is almost ideally suited to an experiment of this type, since there is a comparatively long period, of about 2 weeks, between meiosis and pollen shedding.

A large number of plants were grown in 12-quart pails. Two uniform inbreds, BNL 1 and BNL 130, were used in this experiment. The plants made a satisfactory uniform growth in the pails. Shortly before the stage of meiosis was reached, 4 plants of each inbred were removed to the field, and placed in the 6-meter circle where the radiation received was approximately 1,300 r/d, a dose that previous experience had indicated would be effective in producing mutations. These plants remained in the field for *1 day only*. Each succeeding day a new batch of plants was moved to the field. This program was continued until pollen shedding.

At the conclusion of the radiation part of the experiment, pollen was collected from each group of plants and placed on silks of a recessive stock grown in a field with no radiation. The stocks radiated were all dominant so that we were studying the mutation rate from dominant to recessive for the endosperm characters *su, pr, shwx* and *r* located in chromosomes 4, 5, 9 and 10 respectively.

Some rather striking results were obtained. In the first place 1 day's radiation at 1,300 r gave higher mutation rates (about 3% per gene) than any previously obtained with chronic radiation, although plants had been subjected to 230 r/d for their entire life and 415 r/d for the period from meiosis to pollen shedding. Secondly, there was about a 15 fold increase from the lowest point, just before meiosis, to the period about 1 week before pollen shedding. Following this maximum there was a sudden drop of the mutation rate as measured in the practically mature pollen.

And lastly, the period of meiosis was the most susceptible to pollen damage. Where the plants were radiated at meiosis the percentage of normal appearing pollen was less than 5% with scarcely any pollen functioning, as evidenced by a very low seed set. Within a week after this period, the pollen was hardly distinguishable morphologically from normal, with good sets of seed being obtained.

High Radiation for Short Period

These experiments have demonstrated conclusively that mutations can be induced most efficiently by subjecting the plants to a fairly high radiation for a short period—provided this period is a sensitive one. For corn this occurs about 1 week prior to pollen shedding, but definitely after meiosis which is the pollen sensitive period. Since the pollen is so easily destroyed when radiation is applied at meiosis, it is necessary to get beyond meiosis before putting the plants in the radiation field. This explains the fallacy referred to earlier, of growing the plants for their entire life in the radiation field since the pollen is destroyed at meiosis, long before the sensitive period for the production of mutations. Perhaps mutations are induced at meiosis the same time the pollen grains are killed but a mutation in a dead pollen grain is of no use in plant breeding!

Although we have used only corn in the study of the most effective stage for producing mutations, it seems logical to assume that in other plants the same stages might prove susceptible to change by radiation.

It would be well to grow any plants to be radiated in flower pots or pails and move them to the radiation field shortly before pollen in shed. With plants blooming over an extended period, different stages can be radiated all at one time and flowers can be tagged with the date of opening after the plants are removed from the field. Thus a radiation field can be used for a wide variety of crops and many radiations can be made in the course of a summer. For maximum efficiency in inducing mutations *plants should not be grown in the radiation* field but moved in for a short time only.

In other words, we use a Co^{60} source as a "field irradiation machine." Rather than grow plants around the source for their entire life, a much greater number of plants is brought temporarily near the source for short periods of time during a summer. Looking ahead into the future, since it is not necessary to treat many plants at any given time, the high doses can be obtained by placing the plants comparatively near a small source rather than in larger circles in a field with a big source. Consequently a fairly small source can be used quite effectively for producing mutations.

While the present source of Co^{60} in the Brookhaven Radiation Field is approximately 1,600 curies, we believe that 10%, or a source of approximately 150 curies, would be ample for most purposes. High doses can be obtained by placing plants close to the source. The dosage increases rapidly as one approaches the source due to the inverse square law. For example, the dose at 1 meter is 100 times that at 10 meters.

Somatic Mutations

In addition to gametic mutations there is considerable interest in producing mutations in vegetatively propagated species. We have a rather large planting of orchard crops such as apples, peaches, grapes, blueberries, etc. in our radiation field, planted there with the hope of producing bud mutations. Such mutations could then be propagated vegetatively and a new variety established immediately. Already several cases of a red carnation have been found following the radiation of the White Sim variety. Also, strains of White Sim have been developed without the characteristic red flecks or "sinus blotches" along the margins of a small percentage of the petals. This new type which we call a Blotchless Sim has already attracted the attention of the carnation growers and may be the first variety resulting from a somatic mutation induced in our radiation field. These effects just noted were produced by rather high doses of radiation—about as high as the plant would stand for a prolonged period.

In corn we can also study the effect of radiation on somatic mutations using the pericarp gene (P). Popcorn hybrids heterozygous for the pericarp gene (P/p) were grown in the radiation field, planting from the 15 meter row with radiation of 180 r/d to a distance of 175 meters with less than 1 r/d. Ears from this experiment have been harvested and will be scored for mutations. In addition to these plants some 72 plants were grown in pails and divided into 18 groups of 4 plants each. Beginning when the ear primordium was less than 1 inch long, 2 of these groups of 4 plants each were moved to the field for a radiation of 2 days each at doses of 500 and 1,000 r/d. This program continued until after the corn plants produced silks.

We were interested, but not surprised, to find that in plants grown in these pails a rate of somatic mutations was found that exceeded by far any previously found somatic mutation rate. So it appears that somatic mutations, like

gametic ones, can be produced in abundance, provided the sensitive period is known. It is anticipated there will be considerably more difficulty in determining the sensitive stages for somatic or bud mutations than for gametic ones. The plant breeders will have to know their material, even more exactly than has been necessary heretofore.

It should be mentioned here that Dr. Ingvar Granhall, at the Balsgard Fruit Breeding Institute in Sweden, has been using chronic gamma radiation in comparison with X-rays, fast neutrons, β rays and thermal neutrons in the study of somatic mutations in fruit trees. His Co^{60} source the first year was 2 curies which was increased last year to 20 curies. With these small sources it was necessary to place the material radiated very close to the source to secure an effective dose. After studying the various types of radiations mentioned Granhall concluded that "The γ radiation from a Co^{60} source, finally, seems to offer the most adaptable way of treatment. If strong enough, it can be used for easily controlled and measurable short-time or long-time irradiations without applying any disturbing incisions."

SUMMARY

Radiation has been known to produce mutations in plants and animals for more than a quarter of a century. It was Muller who first suggested that radiation might be useful for the practical breeder. The practical applications of radiation induced mutants in plant breeding were first made in Sweden by the late Dr. H. Nilsson-Ehle and Dr. A. Gustafsson, who secured many mutants of barley having stiffer straw and some strains higher yielding than the parental strains, also definite ecotypes for high and low nitrogen fertilizer, strains shorter and taller than the parent, also earlier and later strains. In this country practically all plant breeding using radiation was initiated following the war when isotopes became plentiful and the use of radiation more common.

Some of the most outstanding developments have been the higher yielding strain of peanuts, also peanuts resistant to leaf spot developed by Dr. Walton C. Gregory; the rust resistant strains of oats developed by Konzak and by Frey and the change of a white carnation to red by radiation, also the development of a White Sim variety of carnation with no sinus blotches.

By studying mutation rates in our "Portable Corn Field" we have learned the stages in pollen formation that give the highest percentage of mutations, also the stages to be avoided (meiosis) because of its extreme susceptibility to pollen damage. Also it has been shown that somatic mutations in corn can be produced abundantly by use of the portable corn field. The most logical way to produce mutations, either gametic or somatic, is to move the plants to the radiation field for a short period of high intensity radiation. This is not only logical; for many reasons it is biological! By using a Co^{60} source as a field irradiation machine, rather than as the center of a field where plants are grown for their entire life, the Co^{60} source is much more efficiently used and can be used to treat a much greater number of plants during a summer. Since it is not necessary to treat many plants at one time, the high doses can be obtained by placing the plants comparatively near a small source rather than in larger circles in a field with a big source. Consequently a fairly small source can be used quite effectively for producing mutations. While the present source of Co^{60} in the Brookhaven Radiation Field is approximately 1,600 curies, we believe that 10% of that would be ample, or a source of approximately 150 curies. Such a source, while a radiation hazard, does not require the elaborate precautions taken to guard against injury when using the big kilocurie source. Thus it becomes more feasible for other investigators to set up radiation fields in other sections of the country and thus increase the speed with which we are able to put atomic energy to work for agriculture.

High Altitude Meadows in Colorado: III. The Effect of Nitrogen Fertilization on Crude Protein Production[1]

Forrest M. Willhite, Hayden K. Rouse, and David E. Miller[2]

A LARGE proportion of hay from high altitude meadows is produced without nitrogen fertilization and harvested at late stages of maturity. As a result, the hay may contain low percentages of crude protein. The production of beef, especially from the standpoint of a cow-calf set-up, which is common in the high altitude meadow areas of Colorado, is closely related to crude protein production. In these areas, where winter feeding is essential for up to 180 days, it is usually necessary to feed protein supplement with the low protein hay in order to maintain a good breeding herd and have a satisfactory calf crop.[3] Many ranchers supplement the hay ration with from 0.2 to 0.8 pounds of crude protein per day for each animal.

This paper reports the results of an experiment conducted on a high altitude meadow in Colorado to determine if the need for large amounts of protein supplement could be partially eliminated through increasing protein production on the ranch by application of high rates of nitrogen fertilizer. Since grasses constitute a major part of the forage plants in the high regions and generally respond well to applied nitrogen, it seemed reasonable to assume that the meadows would show large responses to high rates of nitrogen fertilizer.

The literature on effects of high nitrogen levels on grasses grown at high elevations and short growing seasons is limited. On the other hand, much work has been done and is under way on grasses grown at low elevations, where the growing seasons are much longer. Burton and DeVane[4] give an excellent review of the literature on this subject.

[1] Joint contribution of the Colorado Agr. Exp. Sta. and the Western Soil and Water Management Section, Soil and Water Conservation Research Branch, A.R.S., U.S.D.A. Authorized by the Director of the Colorado Agr. Exp. Sta. for publication as Scientific Journal Series 450. Rec. for publication Aug. 26, 1954.

[2] Agronomist, Colorado Agr. Exp. Sta. and U.S.D.A.; Irrigation Engineer, U.S.D.A.; and Soil Scientist, Colorado Agr. Exp. Sta. and U.S.D.A., respectively.

[3] Morrison, Frank. Feeds and Feeding. Morrison Publishing Co., Ithaca, N. Y. 1948.

[4] Burton, G. W., and DeVane, E. H. Effect of rate and method of applying different sources of nitrogen upon the yield and chemical composition of Bermuda grass *Cynodon dactylon* (L.) Pers., hay. Agron. Jour. 44:128–132, 1952.

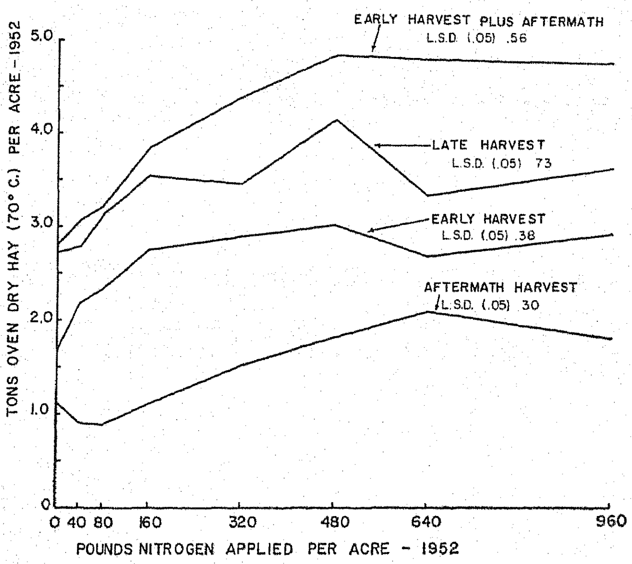

FIG. 1.—Tons of oven-dry hay (70° C.) per acre as affected by rates of nitrogen fertilization and harvest practices, 1952.

Rouse *et al.*[5] found little or no increase in protein yields in the regrowth after an early initial harvest from nitrogen applied in the spring at rates up to 160 pounds per acre. It is possible that higher rates of nitrogen might result in increased growth in the aftermath as well as the initial harvest and so increase the total crude protein production.

MATERIALS AND METHODS

The experiment was conducted near Gunnison, Colorado, during 1952 and 1953 within the confines of a larger experiment initiated in 1950.[5] The area selected had been subjected to sprinkler irrigation and early harvesting in 1950 and 1951.

A split plot design was used wherein each of eight levels of nitrogen were split and two methods of harvest employed. Nitrogen levels were completely randomized in each of four replications. The size of the main plots was 6 by 30 feet; of the split plots, 6 by 15 feet. The entire area received approximately 500 pounds P_2O_5 per acre to eliminate phosphorus as a possible limiting factor.

In 1952 urea was applied broadcast in early spring at the rates of 0, 40, 80, 160, 320, 480, 640, and 960 pounds of nitrogen per acre. Nitrogen rates of 160 pounds per acre or less were applied in a single application, while the higher rates were applied in split applications, to avoid burning of the foliage.

In 1953, the harvest plots were further divided into subplots 6 by 7½ feet. One half was left untreated to study the residual effects of the 1952 nitrogen applications, and the other half was again fertilized with nitrogen on the same basis as in 1952.

The two methods of harvest studied in both years were an early harvest (about July 7) and a late harvest (about August 27). The aftermath on the early harvest plots was cut at the time of the late harvest.

The plots were sprinkler irrigated when the soil moisture tension reached 300 cm. of water at a 6-inch soil depth. Approximately 9 inches of irrigation water were applied each season.

Yields of hay and percentages and yields of crude protein were determined for both years. Crude protein was determined by the Kjeldahl procedure designed to recover only the organic nitrogen.

General Observations

High rates of nitrogen did not result in serious burning of the vegetation either year. The grass, in mid-summer prior to early harvest, ranged in color from a yellowish green on the nontreated areas to a dark green where 960 pounds of nitrogen per acre had been applied. On plots receiving less than 320 pounds of nitrogen per acre the regrowth developed nitrogen deficiency symptoms, but these symptoms did not develop where higher rates had been applied.

In mid-October of 1952, following the late and aftermath harvests, regrowth on the plots treated with 320 or more pounds of nitrogen per acre was greater than on the areas receiving lesser amounts. Where 640 or 960 pounds of nitrogen per acre had been applied, the regrowth grass was about 4 to 5 inches high compared with approximately 1 inch on the nontreated plots.

In the early spring of 1953, temperatures dropped below freezing each night. Under this condition, the areas receiving 640 or 960 pounds of nitrogen per acre the previous spring had produced a growth of about 3 inches by April 15, while the other plots apparently remained dormant. Spring growth appeared to be greater on the areas where late harvesting had been practiced than on the early harvested plots, although this difference was less pronounced at the high rates of nitrogen.

Clovers constituted an appreciable amount of the forage on the nontreated plots. Grasses were stimulated by nitrogen fertilization to such an extent that clover growth was suppressed. Where 320 pounds or more of nitrogen per acre had been applied, clovers were almost eliminated.

RESULTS

Although yields of crude protein are emphasized in this paper, brief discussions of the effect of high rates of nitrogen fertilizer on yields of hay and crude protein percentages are also given.

Hay Yields

The hay yields within the experimental area were much less in 1953 than in 1952. This is probably due in part, to a colder and later growing season in 1953.

EFFECT OF NITROGEN LEVELS APPLIED IN 1952 ONLY

1952 results.—Hay yields were increased by ascending nitrogen rates up to 160 pounds per acre in both the early harvest and late harvest (figure 1). Increasing nitrogen beyond 160 pounds per acre did not result in significantly greater hay yields in either of these harvests. The aftermath did not show a response to nitrogen rates below 320 pounds per acre, and the greatest yield was obtained from the 640-pound rate.

1953 results (residual effects of 1952 applications).—Residual effects of nitrogen applied in 1952 were not significant in 1953 at rates below 160 pounds per acre in the early harvest and 320 pounds per acre in the late harvest (figure 2). Increased rates of nitrogen beyond the above

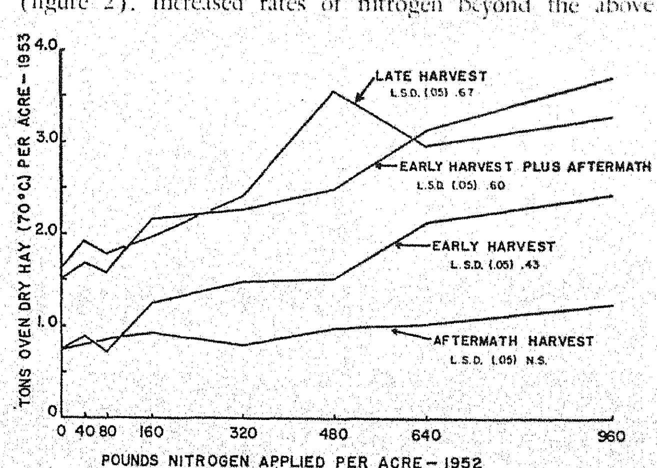

FIG. 2.—Tons of oven-dry hay (70° C.) per acre obtained in 1953 as affected by rates of nitrogen applied in 1952 and by harvest practices.

[5] Rouse, H. K., Willhite, F. M., and Miller, D. E. High altitude meadow in Colorado—I. The effect of irrigation on yields and quality of hay. Agron. Jour. 47:36–40. 1955.

rates generally resulted in greater hay yields although large rate differences were required to show a significant yield change. There were no significant residual effects in the aftermath.

Effect of Nitrogen Levels Applied in 1952 and Reapplied in 1953

1953 results.—A significant yield increase over the no treatment was obtained by applying 80 pounds or more nitrogen per acre to the early harvested areas and 160 pounds per acre or more to the late harvested areas (figure 3). The aftermath required 480 pounds of nitrogen per acre to give a response. Increasing rates of nitrogen up to 640 pounds per acre generally resulted in higher hay yields in all harvests, but large rate increases were required to produce a significant difference. The yields from the 640-pound treated plots were generally larger than from the 960-pound treatment, although the difference was significant only in the early harvest.

Crude Protein Percentages

Effect of Levels of Nitrogen Applied Only in 1952

1952 results.—Crude protein percentages were not increased, compared to no treatment, by rates of nitrogen fertilization below 160 pounds per acre for the early harvest, 640 pounds for the aftermath, and 320 pounds for the late harvest (figure 4). Increasing the rates of nitrogen beyond these amounts resulted in increased protein percentages, although large rate differences were necessary to obtain significant protein changes.

1953 results.—The data presented in figure 5 show that, in general, nitrogen fertilization tended to depress protein percentages in all harvests, compared to no treatment. This tendency is probably a result of less clover growth where nitrogen had been applied. Large applications of nitrogen are apparently necessary to have a residual effect on the protein in the grasses sufficient to offset the absence of clovers. The 960-pound treatment was the only one to yield forage significantly higher in protein than that from the no treatment in any of the harvests.

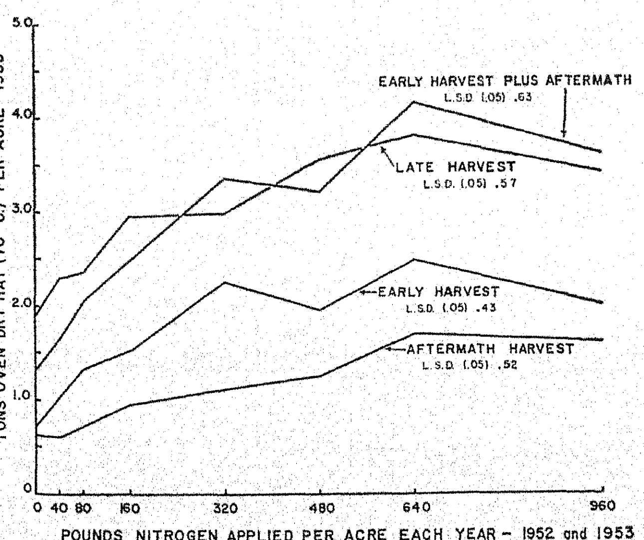

FIG. 3.—Tons of oven-dry hay (70° C.) per acre obtained in 1953 as affected by rates of nitrogen applied in both 1952 and 1953 and by harvest practices.

Effect of Nitrogen Levels Applied in 1952 and Reapplied in 1953

1953 results.—Protein percentages were somewhat depressed by addition of 40 to 80 pounds of nitrogen per acre, compared to no treatment, for all harvests although it was significant only for 80 pounds in the late harvest (figure 6). The protein percentages in the aftermath from the 160 pound treated areas were significantly lower than from the no treatment. Application of 320 pounds or more of nitrogen per acre significantly increased the protein percentages over the no treatment in the early and late harvests, while 640 pounds were required in the aftermath. There were no significant differences between the 480, 640, and 960 pound rates of nitrogen in the early and aftermath harvests or between the 640 and 960 pound rates in the late harvest.

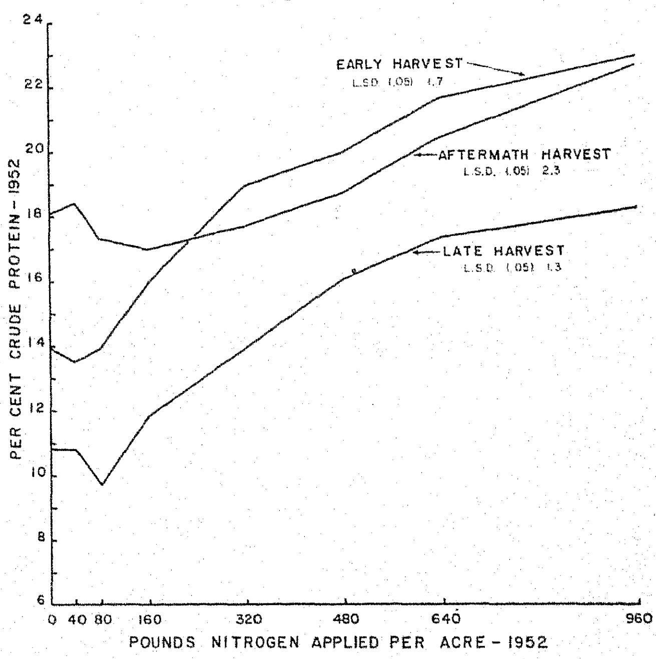

FIG. 4.—Percent crude protein in hay as affected by rates of nitrogen fertilization and harvest practices, 1952. Data based on hay oven-dried at 70° C.

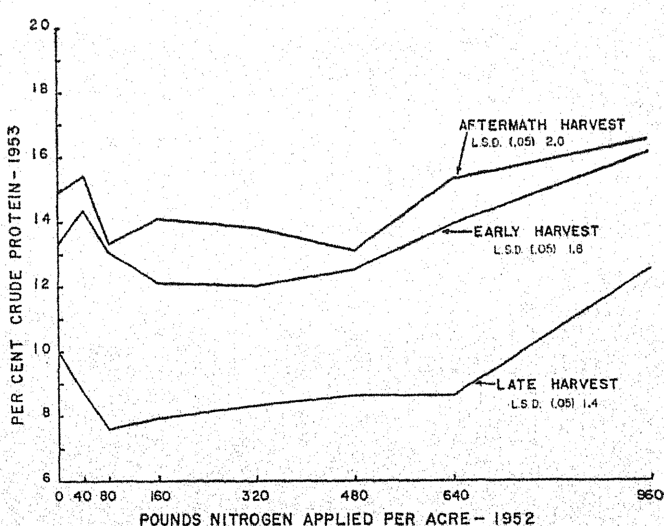

FIG. 5.—Percent crude protein in hay obtained in 1953 as affected by rates of nitrogen applied in 1952 and by harvest practices. Data based on hay oven-dried at 70° C.

Yields of Crude Protein

Effect of Levels of Nitrogen Applied Only in 1952

1952 results.—Yields of crude protein were greatly increased over the no treatment by the high rates of nitrogen in all the harvests, as is shown in figure 7. The 960-pound rate of nitrogen did not give protein yields significantly higher than the 640-pound rate, except in the early harvest.

Application of 40 or 80 pounds of nitrogen per acre did not result in significantly more protein than did no treatment except in the early harvest. Significant responses were generally obtained from 160 pounds or more of nitrogen. The legume growth on the non-fertilized plots apparently produced as much protein as was obtained from fertilizing with 80 pounds of nitrogen per acre where the increased grass growth had depressed the clovers. No significant response was obtained in the aftermath until 320 pounds of nitrogen had been added.

1953 results.—Significant differences over the no treatment were achieved only at relatively high rates of fertilization; 320 pounds per acre for early harvest, 960 pounds for aftermath, and 480 pounds for early harvest plus aftermath and late harvest. The 960-pound rate produced significantly more protein than any other rate in all harvests except the aftermath.

A summary of the residual effects of the 1952 nitrogen applications as observed in 1953 is given in figure 8.

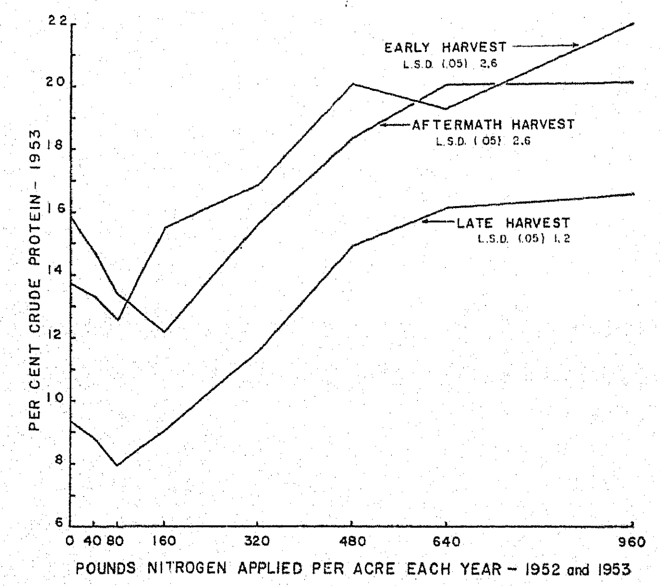

FIG. 6.—Percent crude protein in hay obtained in 1953 as affected by rates of nitrogen applied in both 1952 and 1953 and by harvest practices. Data based on hay oven-dried at 70° C.

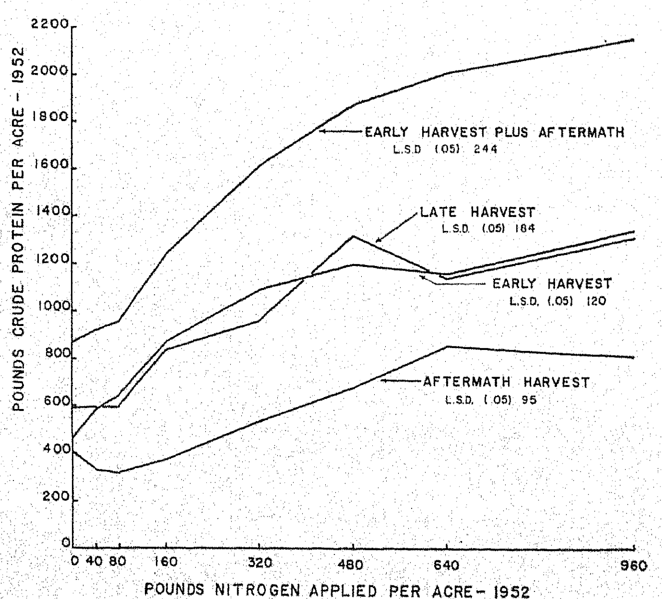

FIG. 7.—Pounds of crude protein per acre as affected by rates of nitrogen fertilization and harvest practices, 1952. Data based on hay oven-dried at 70° C.

Effect of Nitrogen Levels Applied in 1952 and Reapplied in 1953

1953 results.—Reapplying nitrogen in 1953 at the same rates applied in 1952 gave results similar to those obtained in 1952 in that nitrogen fertilization increased protein production, especially at high rates (figure 9). Increases were not as large as were obtained in 1952.

Reapplied nitrogen in the following rates was required to produce significant increases in yield of protein, as compared to no treatment; early harvest—80 pounds; aftermath—480 pounds; early harvest plus aftermath and late harvest—160 pounds. The 640 pound rate produced significantly more protein than any lower rate. The difference between the 640 and 960 pound rates was not significant in any harvest.

Comparison of Equal Total Amounts of Nitrogen Applied Annually and Biennially

Over the 2-year period, 1952 and 1953, comparisons are available showing the effect of applying given rates of nitrogen in 1952 only and applying the same total amount of nitrogen one-half in 1952 and the rest in 1953. The nitrogen rates compared are given in table 1.

In these comparisons, crude protein yields for the 2 years are combined. A summary of these comparisons is given in figure 10 for early harvest plus aftermath and late harvest.

In both the early harvest plus aftermath and late harvest, increasing the rates of nitrogen resulted in increased yields

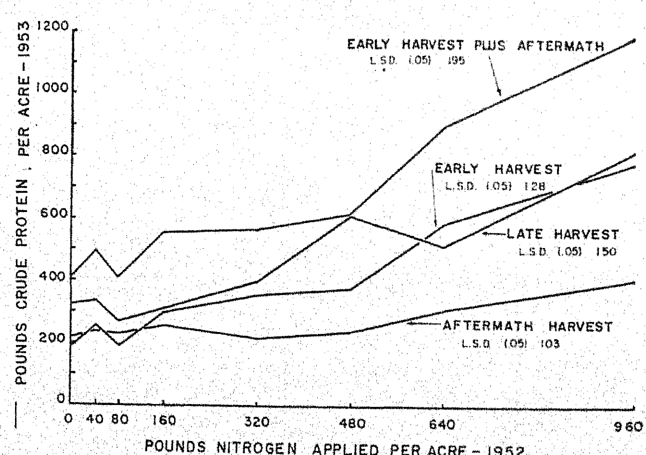

FIG. 8.—Pounds of crude protein per acre obtained in 1953 as affected by rates of nitrogen applied in 1952 and by harvest practices. Data based on hay oven-dried at 70° C.

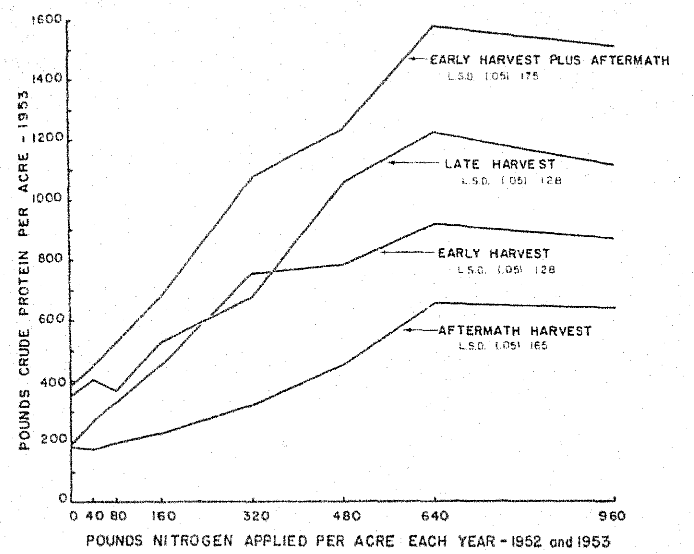

FIG. 9.—Pounds of crude protein per acre obtained in 1953 as affected by rates of nitrogen applied in both 1952 and 1953 and by harvest practices. Data based on hay oven-dried at 70° C.

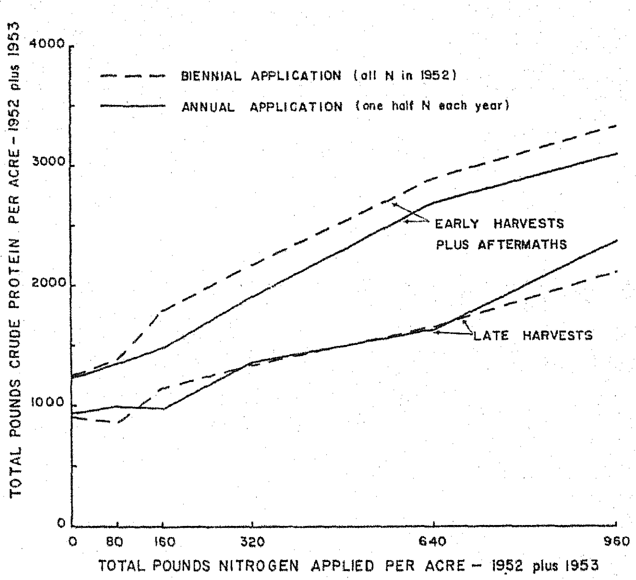

FIG. 10.—Total pounds of crude protein produced in 1952 and 1953 as affected by rates of nitrogen fertilization and annual and biennial application of the nitrogen.

of crude protein. In the early harvest plus aftermath the total yield of protein obtained from applying nitrogen fertilizer every other year was significantly greater than that obtained by applying one half the total amount each year. The difference between annual and biennial applications in the late cut was not significant. There were no significant interactions between rates of nitrogen and annual and biennial applications.

DISCUSSION

The data in figure 10 indicate that nitrogen fertilizer may be successfully applied every other year rather than annually. It should be recognized, however, that the yields of crude protein obtained from a biennial application will probably be much greater in the year nitrogen is initially applied than in the following year. This means that to have a more or less uniform protein production from year to year, with biennial fertilization, one half of the hay producing area should be fertilized one year and the other half fertilized the next year. The data presented here were obtained under conditions of controlled irrigation, and probably do not apply to areas that follow excessive irrigation practices.

It will be noted from the data presented in figures 7 to 10 that the protein production from the early harvest plus its aftermath is much greater than from a late harvest. This indicates the necessity of utilizing a two-harvest system in order to obtain the full benefit of nitrogen fertilization.

Table 1.—Rates used in comparing biennial and annual application of nitrogen, 1952–1953.

Application	Rate (pounds)					
Annual						
1952	0	40	80	160	320	480
1953	0	40	80	160	320	480
Biennial						
1952	0	80	160	320	640	960
1953	0	0	0	0	0	0

The data indicate that a combination of high rates of nitrogen fertilization and good management practices such as controlled, intermittent irrigation, and a two harvest system may result in a substantial reduction in the ranchers' outlay for purchase of protein supplement. However, many details such as the animal utilization of the protein, and general applicability of the experimental data, must be worked out before any recommendations can be made.

SUMMARY

High rates of nitrogen ranging from 0 to 960 pounds per acre were applied to a mountain meadow near Gunnison, Colo., in 1952 and 1953, and their effects on hay and crude protein production were studied. The residual effects of the 1952 applications were studied in 1953. In addition, a two harvest system (early harvest plus aftermath) and a late harvest were compared.

Hay yields were greatly increased by nitrogen fertilization. The highest rates of nitrogen gave the greatest residual effects the year following application.

Protein percentages were generally increased by rates of nitrogen of 320 pounds per acre or greater. A tendency toward decreased protein percentages from the low nitrogen rates was observed.

An application of 160 pounds or more nitrogen per acre was generally necessary to obtain a significant response in protein production in the year nitrogen was applied. Increased protein production was obtained by increasing nitrogen rates to 640 pounds per acre. Significant residual effects were obtained in 1953 only at rates of fertilization where 320 pounds or more nitrogen per acre had been applied in 1952. The application of 960 pounds of nitrogen per acre in 1952 gave the largest residual effect in 1953 of any of the rates studied.

A biennial application of nitrogen fertilizer was as good as or better than an equal total amount of nitrogen applied annually at rates of one half the total amount each year, as measured by total protein production for a 2-year period.

A two harvest system is apparently necessary to obtain full benefits of the high rates of nitrogen fertilizer.

Inheritance of Seedling Reaction to Races 7 and 8 of *Puccinia graminis avenae* Eriks. and Henn. at High Temperature in Three Oat Crosses[1]

F. K. S. Koo, M. B. Moore, W. M. Myers, and B. J. Roberts[2]

THREE major types of stem rust resistance, namely the White Russian, Richland, and "Canadian" types, have been extensively used in oat breeding programs throughout the United States and Canada.

At high as well as moderate temperatures, the White Russian type, including Iowa D69, is responsible for resistance to races 1, 2, 5, 8, 9, 10, and 11 of *Puccinia graminis avenae* while the Richland type, including Rainbow, is responsible for resistance to races 1, 2, 3, 5, 7, 7A, and 12. The "Canadian" type, represented by the selections such as Hajira–Joanette (R.L. 811) and Victoria–Hajira–Banner (R.L. 1276), provides resistance at moderate temperature to all known races except race 7A. The factors for resistance of the first two types were found to be allelic by Smith (4), Cochran *et al.* (1), and Litzenberger (3), while the factor for the "Canadian" type was shown by Foote[3] to be inherited independently from that for either of the first two types. Recently, Welsh and Johnson (5) reported that some selections derived from crosses involving Hajira carry two genes for resistance to all known races except 7A while others have three genes for resistance to all races including 7A. From their results, they concluded that the gene A, which conditions resistance to a group of races, including race 7A, is of the Richland type and that the other two genes, B and C, which together are responsible for resistance to all known races except 7A, are associated in inheritance. They further suggested the possibility that gene C alone causes resistance to all races except 7A. If so, it is analogous to the "Canadian" factor of Foote,[3] and Kehr, *et al.* (2). Studies at Minnesota, reported by Koo *et al.*,[4,5] have shown that all three types of stem rust resistance are combined in selections made from the cross [Landhafer × (Mindo × Hajira–Joanette)] × Andrew. This finding has led to a reconsideration of the hypothesis of allelism of the factors for the White Russian and Richland types of resistance.

Three new crosses were made between one of the selections carrying combined resistance and three varieties, Andrew, Clinton and Gopher, for a study of the nature of this combined resistance and its mode of inheritance. Results of this study have been briefly reported by Myers *et al.*[6] In this paper a more complete account of the results will be presented.

MATERIALS AND METHODS

The selection with combined resistance derived from the cross [Landhafer × (Mindo × Hajira–Joanette)] × Andrew, and designated in this report as LMHJA, was crossed with Andrew, Clinton, and Gopher. The crosses were made in the summer of 1952 and the F_1 and F_2 generations were grown in the greenhouse during the winter and spring of 1952–53. Tests of seedling reaction to races 7 and 8 of stem rust at high temperature (85° F.) of the F_3 lines of the 3 crosses and the parental progenies were carried out in the greenhouse in fall and winter of 1953. The material was first grown at 72° F. until the seedlings fully reached the first leaf stage (about 7 days after planting). At that stage they were inoculated with 1 race, incubated overnight for a period of 16 to 20 hours at 70° F., left for 1 more day at 72° F., and then were grown at 85° F. After about 12 to 14 days, when the rust was fully developed, notes were taken according to the standard scheme for classification of infection types. Four varieties, namely Andrew, Bonda, Hajira–Joanette, and Victoria–Hajira–Banner, were used as the checks in each test.

With only occasional exceptions of intermediate types, plants inoculated with race 7 were classified for reaction as type 1, 1+, or 4, and those inoculated with race 8 were classified for reaction as type 2 or 4. Plants with type 1, 1+, or 2 were considered resistant and those with type 4 susceptible. Plants with no infections were designated as "escapes." Each seedling was marked as to reaction type so that the relationship of reaction to races 7 and 8 could be made on an individual plant basis. In most cases, between 15 and 20 plants were classified for each line. Lines with less than eight infected plants were discarded.

After reaction to the first race was recorded, the leaves were clipped off and the plants were allowed to grow back at 72° F. About 4 to 5 days later, they were inoculated with the other race. Inoculation, incubation, and record taking were carried out as with the first race.

Table 1.—Seedling reactions of plant progenies of LMHJA, Andrew, Clinton and Gopher to races 7 and 8 of *Puccinia graminis avenae* at 85° F.

Parent	No. Progenies	Seedling reaction to	
		Race 7	Race 8
LMHJA	43	R*	R
Andrew	10	R	S†
Clinton	13	S	R
Gopher	17	S	S

* R = resistant.
† S = susceptible.

EXPERIMENTAL RESULTS

The seedling reactions of the 4 parents to races 7 and 8 of stem rust at 85° F. are given in table 1. The LMHJA parent was resistant to both races 7 and 8 as it had been in all previous greenhouse tests. Andrew was resistant to race 7 but susceptible to race 8, Clinton was resistant to race 8 but susceptible to race 7, and Gopher was susceptible to both races.

[1] Contribution from the Agronomy and Plant Genetics Dept. and the Plant Pathology and Botany Dept., Univ. of Minnesota, cooperating. Paper No. 3229, Scientific Journal Series, Minnesota Agr. Exp. Sta. Rec. for publication Aug. 26, 1954.

The writers are indebted to Dr. H. K. Hayes, former chief of the Department of Agronomy and Plant Genetics, University of Minnesota, who, along with others, first made the selections carrying the combined resistance, later set up the crosses for the present study, and has shown continuously his great interest in this problem.

[2] Research Fellow, Agronomy and Plant Genetics Dept.; Instructor, Plant Pathology and Botany Dept.; Head, Agronomy and Plant Genetics Dept., Univ. of Minnesota; and Agent, U.S.D.A., respectively.

[3] Foote, W. H. A study of the inheritance of the stem rust reaction in oats. Ph.D. thesis, Univ. of Minnesota. 1948.

[4] Koo, F. K. S., Goto, S., Myers, W. M., and Moore, M. B. 1952 National Oat Newsletter Vol. III, pp. 45–46. 1953.

[5] Koo, F. K. S., Moore, M. B., Myers, W. M., and Goto, S. Genic relationship of three types of stem rust resistance in certain oat crosses. Presented at 1953 annual meeting, Amer. Soc. Agron. Abstracts. p. 92, 1953.

[6] Myers, W. M., Koo, F. K. S., Moore, M. B., and Roberts, B. J. 1953 National Oat Newsletter Vol. IV, pp. 44–45. 1954.

Table 2.—Seedling reactions to races 7 and 8 of *Puccinia graminis avenae* at 85° F. of F_3 lines of LMHJA × Andrew and LMHJA × Clinton.

Cross	Race used	No. of F_3 lines				P value for a fit to a 1:2:1 ratio
		Resistant	Segregating	Susceptible	Total	
LMHJA × Andrew	7	145	—	—	145	
	8	43	70	32	145	0.50–0.30
LMHJA × Clinton	7	39	87	30	156	0.30–0.20
	8	156	—	—	156	

The seedling reactions to races 7 and 8 of the F_3 lines of LMHJA × Andrew and LMHJA × Clinton are presented in table 2 and that of LMHJA × Gopher in table 3.

In the cross LMHJA × Andrew, all 145 F_3 lines were resistant to race 7 at 85° F., indicating that the factors responsible for resistance to race 7 were the same in the two parents. The classification of the same 145 F_3 lines for reaction to race 8 into resistant, segregating, and susceptible, gave a good fit to a 1:2:1 ratio as indicated by a P value between 0.50 and 0.30, indicating that the reaction to race 8 at 85° F. was governed by a single factor pair.

In the cross LMHJA × Clinton, all of 156 F_3 lines were resistant to race 8 at 85° F., indicating that the factor from LMHJA (presumed to be the White Russian factor) and the one from Clinton (Iowa D69 factor derived from Richland × Green Russian cross) for resistance to race 8 were allelic. The same 156 F_3 lines were classified for reaction to race 7 into resistant, segregating, and susceptible groups. A calculated P value between 0.30 and 0.20 for goodness of fit to a 1:2:1 ratio was obtained, indicating that a single factor pair was responsible for reaction to race 7.

Eighty-five F_3 lines of the cross LMHJA × Gopher were classified as resistant, segregating, and susceptible for the reactions to races 7 and 8 at 85° F. P values between 0.50 and 0.30 for the classification of reaction to race 7 and between 0.30 and 0.20 for that to race 8 for goodness of fit to 1:2:1 ratio were obtained. These results are in good agreement with the assumption that the reaction to each race was conditioned by a single factor pair. There was a close association of reaction to the two races. With two exceptions, the lines resistant or susceptible to one race were also resistant or susceptible to the other and the lines segregating for reaction to one race were also segregating to the other. These results indicate that the factors for resistance to races 7 and 8 were closely linked. The two exceptional lines, one resistant to race 8 but susceptible to race 7 and the other resistant to race 8 but segregating to race 7, can be explained as resulting from crossing over.

Table 3.—Seedling reaction of F_3 lines of LMHJA × Gopher to races 7 and 8 of *Puccinia graminis avenae* at 85° F.

Reaction to race 8	Reaction to race 7: R	Seg.*	S	Total
	No. of F_3 lines			
R	26	1	1	28 †
Seg.	—	38	—	38 †
S	—	—	19	19 †
Total	26	39	20 ‡	85

* Seg. = segregating for reaction.
† P value for a fit to a 1:2:1 ratio—0.30 to 0.20.
‡ P value for a fit to a 1:2:1 ratio—0.50 to 0.30.

Within the segregating lines of all three crosses, there was a predominance of resistant plants over the susceptible ones. The total number of resistant and susceptible seedlings was determined in 70 F_3 lines segregating for reaction to race 8 in the LMHJA × Andrew cross and in 87 F_3 lines segregating for reaction to race 7 in the LMHJA × Clinton cross. The results are presented in table 4. In the former cross, P was between 0.30 and 0.20 indicating a good fit to the theoretical 3:1 ratio, while in the latter P was between 0.05 and 0.01, suggesting a significant deviation from expectation. This deviation was in the direction of an excess of susceptible plants.

For the cross LMHJA × Gopher, the total number of resistant and susceptible plants in the 38 F_3 lines segregating for reaction to both races is shown in table 5. Value of P for goodness of fit to the 3:1 ratio for reaction to race 7 was 0.50 to 0.30 while for reaction to race 8 it was 0.20 to 0.10.

These results substantiate the hypothesis that resistance to each race was determined in these crosses by a single genetic factor with resistance dominant.

In table 5, it is shown that in the 38 segregating F_3 lines of LMHJA × Gopher, the plants resistant to one race were also resistant to the other and the ones susceptible to one race were also susceptible to the other with exceptions of six plants (found in five lines) which were resistant to race 8 but susceptible to race 7 and one plant (found in another line) which was resistant to race 7 but susceptible to race 8. These results give further support to the assumption that the genes responsible for resistance to race 7 and to race 8 were closely linked. The exceptions can be explained as resulting from crossing over.

Table 4.—Classification of seedling reactions of individual plants to race 8 in segregating F_3 lines of LMHJA × Andrew, and to race 7 in that of LMHJA × Clinton at 85° F.

Cross	Race used	No. of plants			P value for a fit to a 3:1 ratio
		Resistant	Susceptible	Total	
LMHJA × Andrew	8	947	290	1237	0.30–0.20
LMHJA × Clinton	7	908	348	1256	0.05–0.01

Table 5.—Classification of seedling reactions of individual plants in F_3 lines of LMHJA × Gopher segregating for reaction to both races 7 and 8 at 85° F.

Reaction to race 8	Reaction to race 7: R	S	Total
	No. of plants		
R	376	6	382 *
S	1	108	109
Total	377	114 †	491

* P value for a fit to a 3:1 ratio—0.20 to 0.10.
† P value for a fit to a 3:1 ratio—0.50 to 0.30.

DISCUSSION

The White Russian and Rainbow (Richland type) factors together condition resistance at all temperatures to all known races of oat stem rust except 4, 6, and 13. The combination of these two genes would provide greater protection from stem rust, except races 4, 6, and 13, than would the "Canadian" factor, since the latter is not effective in conditioning resistance at temperatures of 80 to 85° F. Furthermore, the "Canadian" factor does not provide resistance to race 7A.

Because of the obvious importance of combining resistance of the White Russian and Richland types in the same variety, oat breeders have repeatedly attempted to do so but without success. Smith's (4) results indicated that such a combination would be impossible since the two genes appeared to be allelic. Subsequent results at several stations seemed to confirm this conclusion.

Lines that appeared to be homozygous for both White Russian and Richland types of reaction were obtained at Minnesota from segregating populations of the cross [Landhafer × (Mindo × Hajira–Joanette)] × Andrew. These lines also were homozygous for the "Canadian" factor, obtained from Hajira–Joanette, and the presence of the White Russian and Richland types of reaction was revealed by greenhouse seedling tests to races 7 and 8 at high temperature. Under such conditions, the "Canadian" factor does not provide resistance. Therefore, resistance to either race 7 or 8 or both, which was obtained, would indicate presence of other factors for resistance. This technic has been used also as a necessary tool in the further studies reported in this paper.

It was postulated that the apparent combination of White Russian and Richland types of resistance in these lines derived from the cross [Landhafer × (Mindo × Hajira–Joanette)] × Andrew, might have resulted either from an actual recombination of these two factors or from a combination of one or the other of these two known genes with another previously unknown gene providing resistance at high temperature to race 7 or race 8. Crosses of the selection carrying combined resistance with the three varieties, Andrew, Clinton and Gopher, provide critical evidence for distinguishing between these two possibilities. Andrew is presumed to carry the Rainbow gene (similar to that of Richland) for resistance, while Clinton has a gene similar in behavior to the White Russian gene. Gopher is susceptible to both races 7 and 8 and, therefore, has neither the White Russian nor the Richland gene. Absence of segregation to race 7 in the cross with Andrew and to race 8 in the cross to Clinton shows that the LMHJA selection has either the same or similar factor for race 7 resistance as the one in Andrew and also the same or similar factor for race 8 resistance as the one in Clinton. Results in the cross with Gopher indicate that the two genes are linked in the coupling phase in the LMHJA selection.

There are at least two possible explanations for the combination of the White Russian and Rainbow genes for stem rust resistance in the same lines. It may be that, contrary to previous reports, the genes were pseudo-alleles and that the recombination resulted from rare crossing-over. The other possibility is that unequal crossing-over occurred in the cross of the Landhafer × (Mindo × Hajira–Joanette) selection with Andrew so that the lines with combined resistance carried a tandem duplication of the White Russian and Rainbow genes. Further investigations are in progress to attempt to clarify this point.

Whatever the origin of the combination of resistance may be, these lines are of great value in oat breeding. The White Russian and Rainbow genes can now be combined in new varieties essentially as easily as if they were a single gene. These two closely linked genes condition resistance at all temperatures to all known races of stem rust except 4, 6, and 13. The "Canadian" factor, known from Foote's[7] work to be inherited independently of these two genes, provides resistance at moderate temperatures to all known races except 7A. A combination of the closely linked White Russian and Rainbow genes with the "Canadian" factor in the same variety—a goal easily accomplished from a genetical standpoint—provides a relatively high degree of protection against all stem rust races that are now known to occur. Experimental varieties carrying such stem rust resistance plus the Landhafer gene for crown rust resistance are now in preliminary plot tests in Minnesota.

[7] *Op. cit.*

SUMMARY

F_3 lines of oats from the crosses of LMHJA with Andrew, Clinton, and Gopher were studied for inheritance of seedling reaction to races 7 and 8 of stem rust at 85° F. The results indicate that LMHJA carried two closely linked factors, one for race 7 resistance and the other for race 8 resistance, and that the genes in LMHJA and Andrew for resistance to race 7 were the same or similar, and that the genes in LMHJA and Clinton for resistance to race 8 were also the same or similar. Possibilities regarding the origin of this combined resistance in LMHJA are briefly discussed.

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Seed Setting and Vegetative Vigor of Ladino Clover (*Trifolium repens* Leyss) Clones and Their Diallel Crosses[1]

R. D. Brigham and C. P. Wilsie[2]

A WIDE range of blooming characteristics generally is found among plants of Ladino clover. Under Iowa conditions, due probably to photoperiodic requirements, many plants bloom sparsely, if at all. These plants contribute little to seed production of the population. Other plants bloom and set seed profusely, which suggests that selection for higher seed setting might be possible. The objectives of this study were to investigate the breeding behavior of clones selected for high and for low seed setting and to study the relationship between seed setting and vegetative vigor.

REVIEW OF LITERATURE

Several investigators have noted that white clover and Ladino clover express wide variability in abundance of flowering and amount of seed produced (1, 2, 5, 6, 8). Also, the relatively low level of commercial seed yields has been recognized. In a 2-year study Dessureaux (3, 4) found a wide range of seed setting among 70 clonal lines, but observed high correlation between years. The number of ovules per floret and the percentage of seed-bearing florets were recognized as important factors in Ladino seed production. Knight[3] found a cyclic pattern of flowering in Ladino clover, and suggested a recombination of clones high in combining ability to produce seed of synthetic variety. Thompson *et al.* (7) observed that Ladino clover produced relatively few flowers under conditions favorable for maximum vegetative growth.

MATERIALS AND METHODS

Ten Ladino clover clones, 5 chosen for high and 5 for low seed setting ability, were selected from a replicated clonal nursery and a large recombination block in 1950. These selections traced to California and Oregon certified seed which had been used to establish a breeding nursery in 1946. Selection was visual and based primarily on number of flower heads, but general vigor, density, spread and disease and insect resistance also were important considerations. Seed was harvested in 1950 from the selected clones for use in the evaluation of open-pollination progenies.

The ten clones were vegetatively propagated, grown in 4-inch pots, and allowed to flower under an 18-hour day-length in the greenhouse. Diallel crosses were made, that is, all possible combinations, making a total of 45 single crosses. To determine any possible self-compatibility, one or two heads of each clone were selfed. A microscopic study of pollen was made to check the possibility of aborted pollen grains and consequent lowered cross compatibility.

Seedlings of the 45 single crosses, and open pollination progenies of the parent clones were started in the greenhouse and transplanted to the field in two separate nurseries in May, 1951. Plants were space-planted in randomized complete blocks with four replicates. A clonal nursery of the parental plants also was established at the same time.

Data were recorded in August and in September, 1951, on seed setting, density, spread, vigor and leaf marking. Density and vigor were scored from 1, least desirable, to 9, most desirable. Spread was measured by determining the approximate area occupied by each progeny row. To evaluate seed setting, seed heads were counted in August, but in September and subsequently, plants were scored on a 1 to 9 scale, with 9 indicating the highest seed production. To compare actual seed production with visual seed ratings, seed yields were obtained from 405 plants randomly chosen among the F_1 progenies.

To test performance in the F_2 generation certain single cross progenies were sampled in October, 1951. Three high by high, three low by low, and nine high by low seed-setting crosses were studied. Four plants, randomly chosen from each F_1 progeny, were used for sib-mating. In two single crosses, which appeared to be segregating for seed setting, both a high and a low seed-setting group of 4 plants were chosen. All sib-matings were made in the greenhouse, either by hand crossing or in a bee cage, and F_2 seedlings were transplanted to the field in May 1952.

Open pollination progenies, diallel crosses and parent clones were harvested for forage yields June 24 and Aug. 11, 1952. Plants in these nurseries were again rated for density, spread, seed set and vigor in late July and in September, 1952.

RESULTS AND DISCUSSION

No relationship was evident between seed setting and percentage of aborted pollen in the ten parent clones. There also was no indication of self-compatibility among the ten clones. A correlation of 0.83 was found between actual seed yield and visual scores for seed setting of spaced plants in the single cross progenies. This value, based on a sample of 405 plants, greatly exceeded the 1% level of significance. Among parent clones the correlation between seed yield and number of heads was 0.87 and between number of heads in 1951 and seed-setting scores in 1952 was 0.92. Under the conditions of these experiments insect pollination apparently was not a limiting factor and profuse blooming was a good indication of seed setting. Little increase in accuracy of estimating seed production resulted from counting heads as compared with visually scoring the spaced plants.

Data from the open-pollination progenies indicated that seed-setting scores for 1951 and 1952 were highly correlated, the r value being 0.96. In general, high seed-setting clones produced high seed-setting open-pollination progenies, and low seed-setting clones produced low seed-setting progenies. The autumn rating in the seedling year appeared to give an accurate estimate of seed setting ability in the second year.

The 45 diallel crosses also were scored for seed setting. Average scores of the nine single crosses involving each of the ten parent clones differed at the 1% level of significance. A summary indicating comparative rank based on seed-setting scores of the parent clones, single crosses and open-pollination progenies is given in table 1. It should be noted that the 5 clones originally selected for high seed setting produced both open-pollination and single-cross progenies with the highest scores for seed setting.

When grouped according to seed setting ability of the parent clones, the mean score for the high by high crosses was 6.54, the high by low crosses, 3.59, and the low by low crosses, 1.78. In general, seed setting was intermediate in progenies of high by low seed-setting clones.

Parent-progeny relationships for seed-setting scores indicated high heritability for this characteristic. Correlation between clones and open-pollination progenies (based on scores

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[2] Formerly graduate assistant in Farm Crops and Professor of Farm Crops, Agronomy Dept., respectively. Part of a thesis submitted by the senior author in partial fulfillment of the requirements for the Master of Science degree at Iowa State College.

[3] Knight, W. E. Breeding Ladino clover for persistence and longevity. Ph.D. thesis. Pennsylvania State Univ., library, State College, Pa. 1950.

Table 1.—Seed setting rank of Ladino clover clones, their single crosses and their open-pollination progenies.

Clone number	Seed setting rank based on visual scores		
	Parent clone	Single cross progeny (Mean of 9 crosses)	Open-pollination progeny
High seed setting group			
107	1	1	1
149	2	2	3
236	3	5	5
271	4	4	4
224	5	3	2
Low seed setting group			
213	6	7	7
135	7	6	6
214	8	9	—
229	9	10	8
150	10	8	9

for seed setting) was 0.84, between clones and their single cross progenies was 0.92 and between open-pollination and single cross progenies was 0.92.

A summary of seed-setting scores for typical F_2 progenies is given in table 2. No F_2 progenies were obtained from low × low crosses because of the failure of F_1 plants to bloom. Although variation among F_2 plants from crosses of high seed-setting clones was high, a large proportion of the population was in the three highest score classes. In F_2 populations from crosses 236 × 213 and 271 × 214, sib-matings of F_1 plants selected for high and low seed setting gave markedly different frequency distributions for seed setting. This would indicate the possible effectiveness of selection for high seed setting within single cross progenies.

Forage yields of parent clones, single cross progenies and open-pollination progenies were obtained. Among the parent clones (not previously evaluated for yield of forage) there was a slight, but not significant, negative correlation (−0.273) between forage yield and seed setting.

Forage yields of single cross progenies indicated marked differences among families. In general, yields of reciprocals were similar, with only two exceptions, which could possibly be explained on the basis of the small sample of plants of each cross actually evaluated.

A correlation of 0.29 was found between seed setting and forage yield of the 45 single crosses. This value, although low, exceeded 1% level of significance, suggesting that high yields of both forage and seed are not incompatible.

Vigor scores obtained by visual ratings of the single cross progenies were highly correlated with actual forage yields. Vigor ratings taken in the autumn of the first year were found to be essentially similar to ratings taken during the second year, suggesting that selection for vigor of transplants could be practiced in the fall of the first year. A comparison of clones and their progenies based on vigor scores showed an inconsistent relationship (table 3). However, clones 271 and 213, which had the highest vigor scores, produced open-pollination and single-cross progenies with the highest average vigor scores. It seems likely that vigor is not measured as accurately as certain other characteristics, and its heritability appears low because of effects of the environment and genotype-environment interaction.

Density appeared to be negatively correlated with seed setting. Clone 107, for example, had the lowest density score and the highest seed-setting score. In general, clones with high density scores produced high scoring progenies.

Spread of clones and their progenies was not always consistent, although two of the more spreading clones produced the most spreading open-pollination progenies, and the three most spreading clones produced the most spreading single crosses. The spacing of plants within rows and between rows may have limited spread of some of the more aggressive plants in the second year.

A summary of the leaf marking data indicated that the "V" marked condition was dominant to unmarked. Brown[4] postulated that the homozygous recessive condition of the gene for "V" leaf marking produced pure green leaves with no marking, and that the heterozygous or homozygous con-

[4] Brown, K. G. Inheritance of patterned leaf markings in white and Ladino clover. Paper presented at annual meeting, Amer. Soc. Agron., Cincinnati, Ohio, Nov. 17–20, 1947.

Table 2.—Frequency distribution of seed setting scores in the F_2 generation of Ladino clover crosses among clones differing in seed setting.

Cross	Seed setting score classes*									Total plants	Weighted mean
	1	2	3	4	5	6	7	8	9		
High × High seed setting											
236 × 271	1	1	3	4	5	4	7	20	16	61	7.05
236 × 224	1	6	5	5	4	9	14	18	18	80	6.58
271 × 224	1	1	2	1	2	6	8	9	44	74	7.88
High × Low seed setting											
224 × 213	1	2	0	3	3	1	5	22	30	67	7.75
224 × 214	3	6	6	7	8	14	14	13	7	78	5.77
224 × 229	2	3	7	9	16	13	10	6	1	67	5.22
236 × 213											
Selection for High	1	1	2	2	5	15	20	25	15	86	7.06
Selection for Low	8	6	11	9	4	0	0	0	0	38	2.87
271 × 214											
Selection for High	1	4	4	4	7	10	10	3	2	45	5.42
Selection for Low	26	15	4	0	0	0	0	0	0	45	1.51

* 1 = lowest, 9 = highest.

dition produced leaf marking. Data obtained in this study tend to confirm his results. F_1 and F_2 observed ratios were found to fit expected ratios, as indicated by the "Chi Square" test. Clones 150, 135, and 213 were considered to be heterozygous for leaf marking, Clones 107, 149, 224 and 229, homozygous for leaf marking, and Clones 214, 236 and 271, homozygous for pure green.

SUMMARY

Field studies were conducted to evaluate five high and five low seed-setting clones of Ladino clover. A space planted clonal nursery, an open-pollination progeny test, and a single cross progeny test were established in May, 1951. Seed setting ability was investigated in conjunction with expression of vegetative vigor as measured by estimates of density, vigor and spread of parent clones and their progenies. Actual forage yields also were obtained. Leaf marking was recorded as present or absent on each plant. Parent clones were found to be self-incompatible, and cross-compatible.

Highly significant correlations were found between seed setting of clones and their open-pollination progenies ($r = 0.84$) and their single cross progenies ($r = 0.92$). Correlation of seed setting in single crosses and open-pollination progenies also was high ($r = 0.92$). Selection for high seed setting should be effective, as this characteristic appears to be highly heritable.

A correlation of 0.83 was found for the relationship between visual rating and actual seed production, indicating that a scoring system was fairly accurate for evaluation of seed setting ability in Ladino clover spaced-plants.

Ratings of Ladino clover spaced-plants for seed setting, vigor, density and spread in the autumn of the first year were highly indicative of the performance of these plants in the second year.

Actual forage yields were found to be closely related to scores for spread, vigor and density, suggesting that an overall rating for vegetative vigor could be used as a basis for selection in spaced plants.

The light colored "V" marked condition in leaves of Ladino clover was found to be dominant to the green, unmarked condition. Of the 10 parent clones, 4 were considered to be homozygous dominant, 3 heterozygous and 3 homozygous recessive for leaf marking.

Table 3.—Summary of scores for vigor of parent clones, open-pollination progenies and single cross progenies of Ladino clover.

Clone number	Scores for vegetative vigor*		
	Parent clone	Open-pollination progeny	Single cross progeny (Mean of 9 crosses)
271	9.0	8.7	8.1
213	9.0	8.5	8.1
135	8.5	6.8	7.8
150	7.0	8.2	7.7
236	7.5	7.5	7.6
214	9.0	—	7.5
149	6.5	7.7	7.4
107	5.5	7.0	7.4
224	8.5	7.7	7.1
229	7.5	8.0	7.1

* 1 = lowest, 9 = highest.

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Laboratory Evaluation of Fungicides for the Preservation of Moist Grain[1]

R. U. Schenk and W. K. Kennedy[2]

THE major cause of deterioration of moist foodstuffs is mold growth, and the use of fungicides as moist hay and grain preservatives has been suggested and tried (1,2,3,4). However, when mold growth on moist wheat was inhibited with fungicides, the grain developed off-flavors and odors and the milling and baking quality declined (3,4). Although mold growth was controlled, the grain became unfit for human consumption and the chemical treatment of moist grain was considered not practical.

The possibility of using fungicides to preserve moist grain for animal feed has not been fully explored. If preservatives will prevent mold growth and the accompanying high dry matter losses in moist grain without seriously altering the palatability of the grain, they might be used on grains that are grown for animal consumption. Preserving moist grain with an inexpensive fungicide has some definite advantages over other methods of handling such grain. Equipment costs for applying the chemical would be relatively small compared to drying equipment. The amount of time required for treating moist grain with fungicides would be much less than the average time for drying. Also, chemicals can be purchased on very short notice when their need is indicated.

Dawson, *et al.* reported that under laboratory conditions several of the chlorinated phenols inhibited mold growth in moist hay (1). Schenk and Kennedy confirmed this work and reported that several other compounds also showed promise as hay preservatives (5). Under field conditions Kennedy and Schenk were able to prevent molding and large dry matter losses in moist hay with high rates, of 2,4,6-trichlorophenol, but did not know whether or not the same results would be obtained with moist grain (2).

During 7- and 10-day storage periods, Milner and co-workers found that dry matter losses of moist wheat treated with certain fungicides were small but since the quality of the wheat for human consumption quickly deteriorated, the grain was not stored for longer periods (3,4). Schenk reported that several fungicides not only prevented mold growth on moist grain but inhibited germination and probably curtailed the respiration rate of the grain itself.[3]

As a result of Schenk's work this study was undertaken to determine if certain fungicides could control both mold and grain respiration when used as preservatives for moist grain.

PROCEDURE

Duplicate 100.0-gm. samples of wheat containing 29.0 ± 0.2% moisture were treated with 0.125, 0.25 or 0.50% 2,4,6-trichlorophenol; 0.10 or 1.0% thiourea; 0.05 or 0.10% 1-chloro-2-butanone; or 0.80% ethanol. Two samples of untreated moist wheat were also included. The samples were placed in 250-ml. Erlenmeyer flasks in a 25° C. constant temperature room. The flasks were connected to a source of carbon dioxide-free air and approximately 10 liters of such air was passed through each flask daily. The carbon dioxide which evolved from each sample of wheat was collected and measured. Initially the grain was examined daily, but as the experiment progressed, examinations were made at weekly intervals for visible mold growth. The date of first visible mold growth and the degree of mold were recorded. After 55 days, measurements on completely rotten samples, except the checks, were discontinued but the checks and those which were still well preserved were continued for a total of 79 days. At the end of their respective storage periods the contents of each flask were weighed, oven-dried and reweighed to determine the final wet weight and the total loss of dry matter.

The carbon dioxide was initially removed from the air by forcing the air into the bottom of a 20-inch vertical column of 2.5 N NaOH solution (figure 1). The air was subsequently passed through a sintered glass filter stick, into a 1,000-ml. Erlenmeyer flask containing distilled water and then through another sintered glass filter stick 1,000 ml. of a saturated solution of $NH_4H_2PO_4$. Theoretically, after passing through this saturated salt solution, the air was in equilibrium with 93% relative humidity at 25° C.

The air was then passed by means of a manifold system through the individual flasks of grain. The air from each flask was passed through a drying column containing both a layer of silica gel and a layer of $Mg(ClO_4)_2$. The air then passed through a 2-inch piece of capillary tubing with 0.28 mm. diameter in order to equalize the air flow through all samples. Finally the air was passed through a CO_2 absorption tube containing a weighed amount of Caroxite and $Mg(ClO_4)_2$.

In order to maintain nearly constant air pressure in all flasks a 1,000-ml. flask of distilled water was connected to the manifold by means of a glass tube which was inserted into the water about 2 inches. Any excess air bubbled into the water and out of the flask.

The carbon dioxide evolution was measured for periods of 4 to 48 hours but the results are expressed as mgm. of carbon dioxide per 24 hours. For the first 4 weeks the rate of carbon dioxide evolution was measured daily except week-ends. After this the Caroxite tubes were attached to the apparatus less frequently until final measurements were made at weekly intervals. The air was permitted to flow through the flasks continuously and not just when the Caroxite tubes were attached.

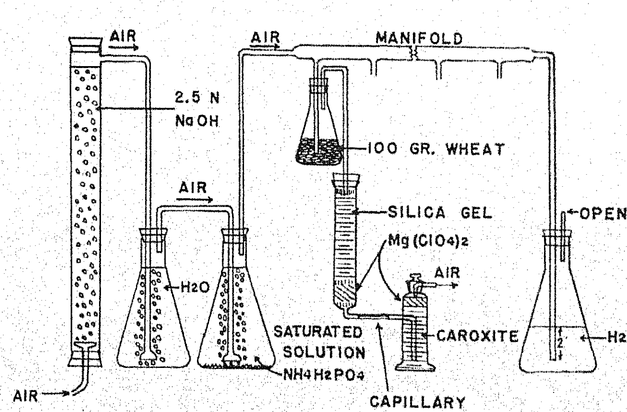

FIG. 1.—Diagram of laboratory equipment used to measure the evolution of carbon dioxide from moist wheat.

[1] Contribution from the Agronomy Dept., Cornell Univ. Agr. Exp. Sta., Ithaca, N. Y. Acknowledgment is made to The Dow Chemical Co. who partially financed the project. Rec. for publication Oct. 2, 1954.

[2] Formerly Research Assistant in Agronomy, Cornell University, now Chemist, U.S.D.A., Northern Utilization Research Branch, Peoria, Ill.; and Professor of Agronomy, Cornell Univ., respectively.

[3] Schenk, R. U. The use of fungicides in the preservation of moist hay and grain. Ph.D. thesis, Cornell Univ., Ithaca, N. Y. 1954.

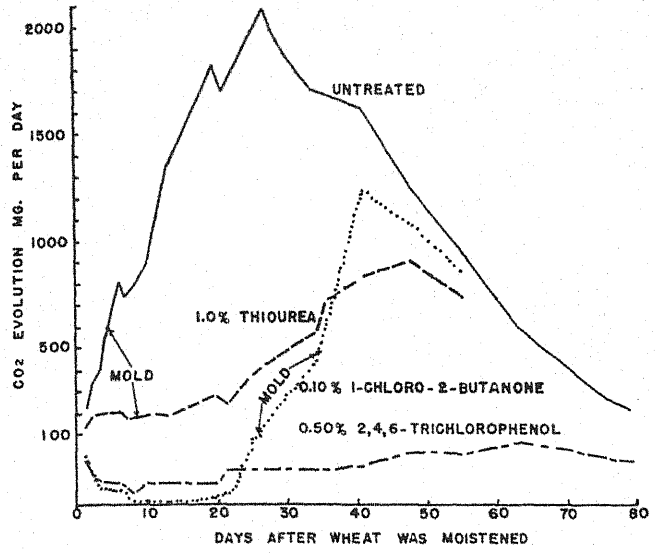

FIG. 2.—Daily evolution of carbon dioxide from treated and untreated moist wheat (mean of two flasks).

RESULTS

Visible mold growth appeared on untreated grain 4 days after the test was started. The rate of CO_2 evolution for untreated grain increased very rapidly to a maximum of about 2,000 mgm. per day on the 27th day after the test was initiated (figure 2). The daily CO_2 evolution steadily declined to about 200 mgm. per day at the time the test was discontinued on the 79th day. During this 79-day period 46.8% of the dry matter was converted to CO_2 and water (table 1 and figure 2).

Treating the grain with thiourea delayed mold development only 3 to 4 days longer than untreated grain, but the rate of CO_2 evolution was much slower. The total loss of dry matter appeared to be somewhat less than for the untreated grain, although the tests were terminated on the 55th day since it was apparent that thiourea allowed too much mold growth to be an effective moist grain preservative.

The rate of CO_2 evolution from the 0.10% 1-chloro-2-butanone treated grain was about 70-mgm. per day the first 24 hours but by the seventh day the rate of CO_2 evolution was only 2 or 3 mgm. per day. The evolution of CO_2 remained low until the 23rd day when it started to increase. The first visible mold growth was observed on one sample on the 25th day and on the other sample on the 33rd day. About the time mold growth became visible, CO_2 evolution increased markedly. The total loss of dry matter for the 55-day period was much lower from the grain treated with 0.10% 1-chloro-2-butanone than from that treated with 1.00% thiourea. The 0.05% application rate of 1-chloro-2-butanone delayed mold growth, but once visible mold growth appeared, the rate of CO_2 evolution and the total loss of dry matter were high.

Treating wheat with 0.25 or 0.50% 2,4,6-trichlorophenol resulted in no visible mold growth, low levels of CO_2 evolution for 79 days and low loss of dry matter. At the end of the 79-day period the kernels of grain were still sound and appeared to be in very satisfactory condition for feeding to livestock. The grain had a slightly rancid taste and was darkened by the chemical but no other undesirable effects were observed. At the 0.125% application rate, trichlorophenol prevented visible mold growth from appearing until the 34th day but then the respiration rate became very high and the total dry matter loss was large.

The more dry matter lost from a sample, the greater the amount of water in the flask when the test was terminated. If the dry matter lost from wheat is assumed to be according to the empirical equation $(C_6H_{10}O_5)_n + 6O_2 \rightarrow 5H_2O + 6CO_2$ each gram of dry matter would liberate 0.555 gm. of water. Since the 100 gm. of wet wheat initially contained 29.0 gm. of water, the predicted amount of water in the flask for a given loss of dry matter would be $Y = 29.0 + 0.555\ X$ where Y = grams of water and X = grams of dry matter lost. The actual values are plotted and the best fit for these values is $Y = 28.4 + 0.542\ X$ with a standard deviation from regression of 0.98 gm. (figure 3). The data indicate that very little if any moisture was lost from the flasks of wheat.

Table 1.—Effect of certain chemicals on time of molding and total dry matter loss in 29% moisture wheat.

Chemical	Rate of application	Time of molding	Time test was terminated	Dry matter loss
	%	days*	days*	%
No treatment	——	4	79	46.8
Ethanol	0.80	4	79	47.2
Thiourea	0.10	7	55	31.0
	1.00	8	55	30.4
1-Chloro-2-butanone	0.05	17	55	38.4
	0.10	29	55	12.3
2,4,6-Trichlorophenol	0.125	34	55	34.5
	0.25	no molding	79	3.6
	0.50	no molding	79	4.9

* Days after the experiment was initiated.

DISCUSSION

In an earlier paper Kennedy and Schenk reported that moist hay treated with an effective fungicide and stored for 8 months still contained enough moisture to allow mold growth to occur (2). Undoubtedly the same situation would be true for moist grain, and in addition the respiration of the moist grain itself might be a problem. The apparatus used in this study provided a rigorous method for testing fungicides to determine how well they control mold growth and to what degree they control other respiration losses in

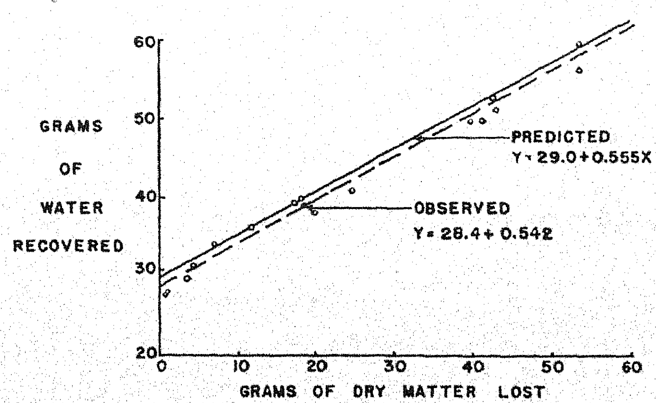

FIG. 3.—Relationship between grams of dry matter lost and grams of water recovered from moist wheat.

moist grain over a prolonged storage period. Since the procedure outlined in this paper requires considerable attention and apparatus, it is suggested that its use be limited to the testing of compounds that prove to be effective in the preliminary laboratory tests proposed by Schenk and Kennedy (5).

Under the conditions of this experiment, trichlorophenol was the only chemical tested which was satisfactory for treating moist grain that was to be stored until fed. Since trichlorophenol may influence the palatability of grain fed to chicks and appear as residues in milk of dairy cows eating treated hay (2,5), its use as a grain preservative needs further study. If grain treated with trichlorophenol made up only a part of the concentrate mixture fed to livestock it is possible that neither palatability nor chemical residues would rule out its use.

The chemical 1-chloro-2-butanone might be very suitable for treating moist grain which had to be held for 1 to 3 weeks during peak periods of harvest until equipment was available for proper drying. Since this chemical is quite volatile and the drying process would probably drive off most of the chemical, palatability and residues might not be limiting factors.

SUMMARY

The evolution of CO_2 and loss of dry matter was measured on wheat containing 29.0% moisture, both treated and untreated with test fungicides. The chemicals and rates of application used in this study were 2,4,6-trichlorophenol at 0.125, 0.25 and 0.50%; 1-chloro-2-butanone at 0.05 and 0.10%; thiourea at 0.10 and 1.00%; and ethanol at 0.80%. Untreated and ethanol treated wheat molded in 4 days and had the highest rate of CO_2 evolution and the highest dry matter loss. Thiourea delayed mold growth for 3 or 4 days only but it did lower the rate of respiration as compared with untreated wheat. The chemical 1-chloro-2-butanone delayed mold growth for about 1 month, and it was very effective in reducing the CO_2 evolution for the first 23 days of storage. When the wheat treated with 1-chloro-2-butanone started to mold, the respiration rate increased rapidly and exceeded the maximum rate for the thiourea-treated wheat.

At 0.25% and 0.50% rate, 2,4,6-trichlorophenol prevented mold growth for the entire 79 day storage period. Dry matter loss during this period was less than 5% and at no time did the respiration rate exceed 100 mgm. of CO_2 per day. Of the chemicals tested, only trichlorophenol appears to be sufficiently effective for treating moist grain that will be subjected to a prolonged storage period. If moist grain had to be held for only 1 to 3 weeks until it could be artificially dried to a safe moisture level, 1-chloro-2-butanone might be of value. Consideration must be given to the toxicological problems associated with the use of these chemicals.

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Inheritance of Resistance to Fusarium Wilt of Flax in Dakota Selection 48-94[1]

P. F. Knowles and Byron R. Houston[2]

THE flax varieties grown on the largest acreage in desert areas of California are susceptible to Fusarium wilt (*Fusarium oxysporum f. lini* (Bolley) Snyder and Hansen). These varieties are Punjab (C.I. 20), now relatively unimportant, and Punjab 47 (C.I. 1115) and Imperial (C.I. 1114), both selections of Punjab. Although wilt has not caused serious economic loss, the disease is increasing, and some fields are infested to a point where susceptible flax varieties can no longer be grown.

Coincident with efforts to find resistant materials in local and introduced varieties (10, 11), a breeding program has been underway to develop resistant varieties by hybridization and backcrossing. Dakota (C.I. 1071) selections have been used rather extensively in this program. This report includes data obtained from crosses of one of these selections with Punjab, Punjab 47 and a second Dakota selection.

LITERATURE REVIEW

The literature would indicate that the inheritance of resistance to Fusarium wilt in flax is complex. Tisdale (13) and Burnham (5) concluded that the inheritance of resistance could not be explained on the basis of a few genes. In a study of F_3 lines from a cross of Dakota with an Indian variety, Chu and Culbertson (6) found several lines with wilt resistance equal to that of Dakota, but none as susceptible as the Indian variety.

In some crops, genes for resistance to Fusarium wilt have been identified. Wade (14) found that resistance to wilt in canning peas was due to a single dominant gene. Resistance to near-wilt in the same crop was shown by Hare, *et al.* (8) to be due to a second dominant gene. In cabbage, high resistance was reported by Walker (15) to be due to a single dominant gene, though Anderson (1) found that moderate resistance was not simply inherited. This moderate resistance was believed to be due to several genes that were cumulative in effect and not dominant. One variety of cabbage was shown by Blank (3) to consist of some plants with a high type of resistance, and the rest with moderate resistance. A single dominant gene was found by Bohn and Tucker (4) to give resistance to wilt in tomatoes. Fahmy's data (7) for cotton suggested that a single dominant gene was responsible for resistance, though Smith (12) reported that resistance in sea-island cotton was due to two dominant pairs of factors. The difference in resistance of three varieties of watermelon was considered by Bennett (2) to be due to a number of genetic factors which were cumulative in their effect.

MATERIALS AND METHODS

Dakota 48-94 is a highly wilt-resistant selection of Dakota that stems back to a single plant in 1948. Each of the four crosses of this study was made between a single plant of this selection and single plants of the wilt-susceptible varieties Punjab, Punjab 47 and Dakota 48-90. Dakota 48-90 is a single plant selection of Dakota. The segregating generations and parental materials that were included in wilt tests through the period 1949 to 1954 are listed in table 1. One test was grown on naturally infested soil from the Burns Field near Pescadero in San Mateo County, and the remainder on steam sterilized soil inoculated with one of three wilt clones. Each clone developed from a single conidiospore, and each was maintained in its original form by constant selection. Clone 287 was obtained from Imperial Valley, clone 294 from the same location of the Burns Field as the naturally infested soil referred to above, and clone 33-1 from the Goat Ranch, also in San Mateo County. Inoculum, as a water suspension of spores, was applied directly to the seed in the row before covering the seed with soil. Previous reports (9, 10, 11) describe the technique of inoculation in more detail.

All tests were grown in greenhouse flats. Each flat was usually sown to 12 rows, with 2 of them parent varieties. An attempt was made to obtain about 50 seedlings in each row. Where less than 10 seedlings were obtained in a row the data from such a row were not used.

The number of wilted seedlings in each row was recorded at frequent intervals, and such seedlings pulled. A test was usually concluded when 95 to 100% of the seedlings of the susceptible parents were affected by wilt, which was 3 to 6 weeks after planting. When the last count was made, wilted plants included those that were dead or showing obvious symptoms of wilt. Wilt was expressed in percent of the total number of emerged seedlings.

With the exception of materials inoculated with clone 33-1, the conclusion of a test found most plants either healthy or definitely affected by wilt. Consequently, a delay of 2 or 3 weeks would not appreciably increase levels of infection. When clone 33-1 was the inoculum, infection did not taper off sharply. The result was many questionable plants at the conclusion of a test, and appreciably higher infections from week to week even after the susceptible check variety had succumbed.

RESULTS

Punjab × Dakota 48-94

Seven F_2 rows and 180 F_3 lines from a cross of Punjab with Dakota 48-94 were grown in comparison with the parents on naturally infested soil. The distribution of parental rows, F_2 rows, and F_3 lines (F_2 progenies) among 21 wilt infection classes is given in table 1. Slightly less than half of the F_3 lines were highly susceptible, and like Punjab. A small but distinct group appeared to be as resistant as Dakota 48-94. The remaining lines were distributed over a wide range, but there was a well marked group with a range of 11 to 40% wilt, and another not so well marked with 41 to 75% wilt. The latter was like the F_2.

The behavior of these materials suggested that the resistance of Dakota 48-94 was due to two complementary genes, which have been termed Fu_A and Fu_B, but referred to as the "A gene" and "B gene" for the purposes of convenience. This hypothesis would assume that the genotype of Dakota 48-94 is AABB, and of Punjab aabb. The porportions and behavior of different genotypes obtained in F_2 would be:

Genotype	Wilt resistance	Percentage wilt in progeny of F_2 plants
1AABB	resistant	0
2AaBB	resistant	25
2AABb	resistant	25
4AaBb	resistant	43.75
1AAbb	susceptible	100
2Aabb	susceptible	100
1aaBB	susceptible	100
2aaBb	susceptible	100
1aabb	susceptible	100

[1] Contribution from the Agronomy and Plant Pathology Depts., Univ. of California, Davis, Calif. Rec. for publication Oct. 7, 1954.

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On this hypothesis F_3 lines should fall into 4 infection groups in the ratio 1:4:4:7. The level of resistance among those genotypes termed resistant is believed to vary slightly, being greater with greater numbers of genes for resistance. A similar situation is believed to prevail to a lesser extent in the susceptible group, with susceptibility increasing with greater numbers of recessive genes.

The infection of the F_2 varied from 46 to 68% with an average of 57.6%. This is higher than that suggested in the model above. It is possible that other organisms may have raised the level of infection in the F_2, though this is rather unlikely because the resistant parent was unaffected. It is probable that some plants of the genotype AaBb, or even of the genotypes AaBB and AABb, may have succumbed in this test.

The group of highly resistant F_3 lines is believed to have stemmed from F_2 plants of the genotype AABB, though the average infection of these 16 lines is 2% and that of Dakota 48–94 is 0.1%. Presumably Dakota 48–94 has modifying genes giving it slightly more resistance than plants of the genotype AABB.

The susceptible group of F_3 lines which averaged 97.8% wilt, would be derived from F_2 plants with the 5 genotypes AAbb, Aabb, aaBB, aaBb and aabb. Although the 81 F_3 lines of this group fell into a single group at the end of the test, they were widely different a few days after the first seedlings had wilted. It was not possible, however, to explain these differences on a genetic basis. If the genes A and B alone gave any resistance it was of a transient nature.

The group of F_3 lines with 11 to 40% wilt was considered to be progenies of F_2 plants with the genotype AaBB or AABb. Both genotypes gave the same breeding behavior when comparisons were made at different dates after planting; there was no tendency for a split into two sub-groups. There was an average of 27.7% wilt in this group, slightly more than the expected 25%. It would appear that the genotypes AABB, AaBB and AABb are highly resistant to wilt, and AAbb and aaBB susceptible.

The average infection of the second intermediate group was expected to be 43.75%, since it included progenies of F_2 plants with the genotype AaBb, the same genotype as the F_1. The average infection of this group actually was

Table 1.—Distribution by wilt infection classes of F_1, F_2, F_3 lines (F_2 progenies), backcrosses, and parents of the flax crosses, Punjab × Dakota 48–94, Punjab 47 × Dakota 48–94, and Dakota 48–94 × Dakota 48–90.

Parent or generation	Number in 5% infection classes																					Average infection, percent
	0	1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–75	76–80	81–85	86–90	91–95	96–100	
Punjab × Dakota 48–94	Grown in naturally infested soil, Sept. 16 to Oct. 18, 1949																					
Punjab rows																					21	99.9
Dakota 48–94 rows	20	1																				0.1
F_2 rows											1	2	1	2	1							57.6
F_3 lines	7	8	1‖	†3	3	10	9	11	5	‖8	6	8	4	7	3	6‖		1	3	7	70	63.6
Punjab × Dakota 48–94	Grown in inoculated soil, Dec. 19, 1950, to Jan. 26, 1951																					
Inoculated with clone 287																						
Punjab rows																					10	99.2
Dakota 48–94 rows	10																					0.0
F_3 lines	8		‖1	2	4	9	3	‖5	5	5	3	7	‖1	2	3	3	6	5	6	6	12	55.0
Inoculated with clone 294																						
Punjab rows														1		1			1		7	91.6
Dakota 48–94 rows	10																					0.0
F_3 lines	5	4	1		‖2	5	6	6	3	‖2	5	3	6	2	3	1‖		5	7	11	19	60.9
Average of inoculations with clones 287 and 294																						
Punjab rows																		1	1	1	7	
Dakota 48–94 rows	10																					
F_3 lines	4	4	2			‖10	7	‖1	3	4	7	6	3	2‖		3	4	1	12	11	12	
Punjab 47 × Dakota 48–94	Grown in inoculated soil: Test 1, Dec. 29, 1953, to Feb. 12, 1954; Test 2, Apr. 22, to June 3, 1954																					
Inoculated with clone 294																						
Test 1 and 2																						
Punjab 47 rows																					10	99.6
Dakota 48–94 rows	8		1				1															3.5
F_1* rows	2																					0.0
F_2 rows									1													38.5
F_3 lines	1				‖5	4	3	3	‖2	1	4	1	1‖						7	9	17	67.5
Inoculated with clone 33–1																						
Test 1																						
Punjab 47 rows																1	2	3		1	1	83.9
Dakota 48–94 rows	3	5																				1.1
F_1* rows			1		1																	14.5
F_2 rows								1														32.5
F_3 lines		1	4	1	4	2	2	3	2	7	1		2	1		1	1	2	2	1	1	42.4
Test 2																						
Punjab 47 rows																				1	1	96.5
Dakota 48–94 rows		2																				4.0
F_3 lines						1			1	1	2	1	4	2	1		2	1	1	2	1	64.2
Dakota 48–94 × Dakota 48–90	Grown in inoculated soil, Apr. 22 to June 3, 1954																					
Inoculated with clone 294																						
Dakota 48–90 rows																				3	3	99.2
Dakota 48–94 rows	5	1																				0.2
F_1 rows	1																					0.0
F_2 rows										1												43.0
Backcross rows																	1					77.5
F_3 lines	3				‖2	4	3‖	3	5	1‖						3	4	3	6	3		53.3
Inoculated with clone 33–1																						
Dakota 48–90 rows	1	5																				1.1
Dakota 48–94 rows		1																				3.0
F_1 rows	1																					0.0
F_2 rows		1																				3.5
Backcross rows	1																					0.0

* Includes reciprocal cross also.
† Double lines separate the F_3 lines into 4 infection classes.

Table 2.—Distribution by wilt infection classes of 150 F_4 lines derived from 15 F_2 plants believed to have the genotypes AABb or AaBB.

Parent or generation	Number of F_4 lines by 5 and 10% infection classes*										
	0–5	6–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100
Dakota 48–94	15			1							
Punjab							1			2	13
F_4 lines	30 ‖†	6	21	35	17	2	1 ‖	1	3	9	25
Expected‡	37.5				75				37.5		

* In soil inoculated with clone 294.
† Double lines separate the F_4 lines into 3 infection classes.
‡ Expected ratio of F_3 genotypes giving rise to F_4 lines 1 AABB: 2 AABb or AaBB: 1 AAbb or aaBB.

56.2%, considerably higher than expected, but not greatly different from the F_2 with 57.6%. The behavior of the group above from genotypes AaBB and AABb suggested that genotypes AABb and AaBB were highly resistant, so the increases in infection—about 13%—of the F_2 and the F_3 lines of the present group would be due to plants of the genotype AaBb that succumbed to wilt. This means that about one-half of the expected 25% of the F_2 population with genotype AaBb did not survive.

The number of F_3 lines in the 4 infection groups was found to fit a 1:4:4:7 ratio rather closely, with the value of P for a Chi-square test lying between 0.5 and 0.3.

Many of the F_3 lines of this study were also grown in the field in the absence of wilt. From each of 16 of the F_3 lines which had shown 11 to 40% wilt in the greenhouse, 10 single plants were taken and their progenies (F_4) grown in soil inoculated with clone 294. It was expected that one-quarter of these F_4 lines would be highly resistant, one-half like the F_3 with 25% wilt, and one-quarter susceptible like the Punjab parent. The F_4 lines derived from 15 of the 16 F_3 lines behaved as expected (table 2). A Chi-square test (table 2) indicated a good fit (P = 0.5 to 0.3) between the actual and expected behavior of these F_4 lines. In one F_3 line all 10 plants gave rise to progenies that were highly resistant—this F_3 line actually had been rather resistant, showing only 12% wilt.

The susceptible F_4 lines should be homozygous for one dominant gene and one recessive gene; their genotypes should be AAbb or aaBB, with equal numbers of each. It is planned to identify these two genotypes.

A wilt test of 100 F_3 lines from a cross of a second plant of Punjab with Dakota 48–94 was carried out using inoculated soil—one F_3 line was discarded because of a suspected error in planting and three were discarded because there were very few seedlings obtained. One replicate was inoculated with clone 287, and the second replicate with clone 294. The pattern of the infection (table 1) was similar to the previous test, with the F_3 lines falling into four groups. With the different clones there were slight differences in infection, clone 294 giving slightly higher levels of infection in the three groups showing susceptibility. For both clones the frequency of F_3 lines in the 4 infection groups showed a satisfactory fit to a 1:4:4:7 ratio (P = 0.7 to 0.5 for clone 287 and 0.5 to 0.3 for clone 294).

The infections of F_3 lines by these two clones are compared in more detail in figure 1 by using a correlation diagram. It would appear that both clones identified the same highly resistant, and the same highly susceptible, F_3 lines. But there was some overlapping in the distribution of the two groups of F_3 lines with intermediate amounts of wilt. Since these clones gave similar infections, the data of the two replicates were averaged (table 1). As expected, the F_3 lines fell into four groups approximately in the ratio 1:4:4:7—a Chi-square goodness of fit test gave a P value of 0.2 to 0.1.

Punjab 47 × Dakota 48–94

From a cross of Punjab 47 × Dakota 48–94, F_1, F_2 and 60 F_3 lines were grown in 2 series, one inoculated with clone 294, the other with clone 33–1. In each series there were duplicate rows of F_1, F_2 and each F_3 line. Forty of the F_3 lines were grown with the F_1 and F_2 in Test 1, and 20 F_3 lines in Test 2. The results from two of these F_3 lines were not used because the number of plants was small.

As expected when inoculated with clone 294 (table 1) there was a distinct class highly resistant to wilt, and one equally distinct that was susceptible. However, some difficulty was experienced in deciding upon a dividing line between the two intermediate classes. Since the F_2 showed an average of 38% wilt, and since both the F_2 and one of the intermediate classes are presumed to stem from the genotype AaBb, it was decided to divide the 2 intermediate classes at 35% wilt. On this basis the fit to a 1:4:4:7 ratio

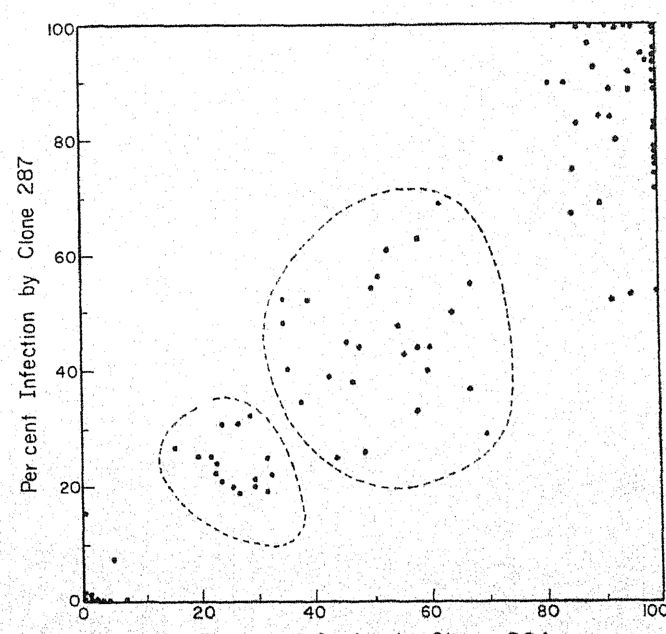

FIG. 1.—Comparison of infection of 96 F_3 lines from the cross, Punjab × Dakota 48–94, by 2 clones of Fusarium wilt.

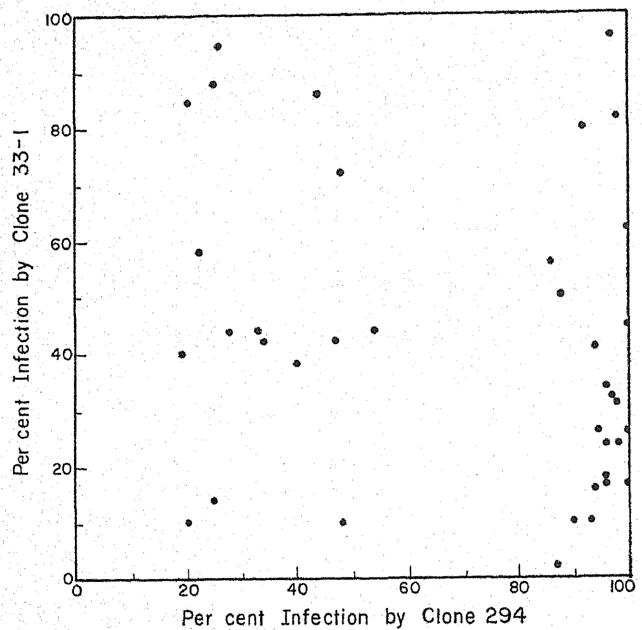

FIG. 2.—Comparison of the infections of 38 F_3 lines from the cross, Punjab × Dakota 48–94, by 2 clones of Fusarium wilt.

was only fair (P = 0.10 to 0.05)—a similar fit (P = 0.10 to 0.05) to a 1:8:7 ratio was obtained if the 2 intermediate classes were combined. It would appear that Punjab 47, like Punjab, has the genotype aabb.

The data obtained from the series inoculated with clone 33–1 bore little similarity to those obtained with clone 294. Within the series inoculated with clone 33–1 the correlation of wilt infections of duplicate rows of F_3 lines (r = 0.83) was not as high as that for duplicate rows inoculated with clone 294. When the average infections of F_3 lines by each the level of wilt infection of F_3 lines was higher in the second than in the first test, so it was not possible to combine such data from both tests as was done for inoculations with clone 294. When the average infection of F_3 lines by each clone in test 1 were compared (figure 2), no similarity was found. It would appear that genes A and B are not involved in resistance to clone 33–1. Dakota 48–94, therefore, must have another gene or other genes that give it a high degree of resistance to this clone. Resistance to clone 33–1 equal to the resistance of Dakota 48–94 would seem to be difficult to achieve in F_3 lines—only 1 out of 58 lines would qualify. This would suggest that there are several genes involved in the resistance of Dakota 48–94 to clone 33–1. However, though the F_3 lines did not fall into distinct classes, they appeared to show a bimodal distribution in both Test 1 and Test 2, with about one-quarter of the lines like the susceptible parent, and three-quarters resistant or partially resistant. Eight F_3 lines were considered susceptible in the first test, and 4 in the second, a total of 12 out of 58. A Chi-square test (P = 0.5 to 0.3) would indicate that this was a good fit to a 3:1 ratio.

It is obvious from figure 2 that the gene or genes for resistance to clone 33–1 are inherited independently of the genes A and B. Among the 16 F_3 lines with intermediate levels of resistance to clone 294 there were 3 resistant, 8 intermediate in resistance, and 5 susceptible to clone 33–1, a close fit to a 1:2:1 ratio (P = 0.8 to 0.7 in a Chi-square test). The F_3 lines susceptible to clone 294 did not show such a clear cut split into 3 groups, though there would appear to be 7 resistant, 12 intermediate in resistance, and 3 susceptible to clone 33–1, again a good fit to a 1:2:1 ratio (P = 0.5 to 0.3 in a Chi-square test).

Dakota 48–94 × Dakota 48–90

F_1, F_2, F_3 and backcross materials from the cross, Dakota 48–94 × Dakota 48–90, were grown in a test inoculated with clone 294. These materials, excepting the F_3 lines, were also inoculated with clone 33–1 in the same test. The data (table 1) are averages of two replicates.

The pattern was the same as in previous crosses, when clone 294 was the inoculum. The F_1 was resistant, the F_2 showed 43.0% wilt, and the F_3 lines segregated in a 1:4:4:7 ratio (P = >0.9 in a Chi-square test). The F_1 of the backcross, Dakota 48–90 (Dakota 48–94 × Dakota 48–90 F_1), had 77.5% wilt when it was expected to have 75% if Dakota 48–90 has the genotype aabb.

Inoculations with clone 33–1 indicate that both parents have the same genes for resistance to this clone, since neither the F_1, F_2 nor backcross populations showed more susceptibility to wilt than the parents. It is possible that the parents have different, but allelomorphic genes for resistance, though this is unlikely since both came from the same variety.

Summary of data from all crosses

Adding together all the data from the three crosses of this study, and considering only situations where data were obtained from naturally infested soil of the Burns Field or from soil inoculated with clone 294, the frequencies of F_3 lines in the 4 infection classes (30, 82, 86, and 176) approximate a 1:4:4:7 ratio (P = 0.2 to 0.1 in a Chi-square test). The range of the infection classes varied from cross to cross in accordance with the distribution of F_3 lines (table 1); the "break" between infection classes coincided with the classes having low frequencies or was marked by a gap in the distribution of F_3 lines.

Backcrosses

The genes A and B are being transferred to Punjab 47 and Imperial by backcrossing; since Imperial, like Punjab 47, is a selection of Punjab, it is presumed to have the genotype aabb. The usual procedure has been to grow F_2 on wilt-infested soil and backcross surviving plants to the recurrent parents. In some instances the F_2 has been grown in soil inoculated with clone 294, though it has been more convenient to grow the F_2 in naturally infested soil of the Burns Field, where clone 294 was obtained. In making these backcrosses, the only gamete conferring wilt resistance in the hybrid and its progeny will be AB, giving a backcross F_1 with the genotype AaBb. In other words, if the backcross F_2 populations show resistance to wilt they should have the same proportion of susceptible plants as F_2 populations of this study, namely 35 to 70%. F_2 populations of the third backcross of resistant materials of the cross, Punjab × Dakota 48–94, to Punjab 47 and Imperial were grown in the greenhouse in soil inoculated with clone 294 and in naturally infested soil of the Burns Field; they were not duplicate plantings. As expected, some F_2 populations were very susceptible, these stemming presumably from the union of the gametes Ab, aB, or ab with the ab gamete of the recurrent parent. The average infection of those considered resistant (48 out of 69 in the field and 52 out of 112 in the greenhouse) was 48.3% in the field and 62.0% in the greenhouse. Such F_2 populations with some resistance are believed to stem from F_1 plants with the genotype AaBb.

The backcross F_2 populations of the Burns Field were also grown on wilt infested soil of the Goat Ranch, the source of clone 33–1. Populations susceptible on the Burns Field were also susceptible on the Goat Ranch. But the F_2 populations believed to stem from the F_1 genotype AaBb and showing some resistance in the Burns Field were in most cases highly susceptible on the Goat Ranch, though a few were partially resistant. This might be expected in the light of the behavior of F_4 lines inoculated with clone 33–1, when it was assumed that genes for resistance other than A and B in Dakota 48–94 gave resistance. The small number of backcross F_2 populations with resistance to wilt on the Goat Ranch would be a consequence of no selection for such resistance; all backcross F_2 populations were grown on naturally infested soil of the Burns field or on soil inoculated with a wilt clone therefrom. If one gene gives resistance to the wilt of the Goat Ranch, and there has been no selection for this resistance, 1/8 of the F_1 plants from the third backcross to the susceptible parent should be heterozygous for this gene; their progeny should exhibit some resistance. Actually 7 out of 69 F_2 populations from the third backcross showed resistance to wilt on the Goat Ranch, if a population is resistant with less than 71% wilt.

DISCUSSION

It was not surprising in this study to find the flax varieties Punjab and Punjab 47 devoid of genes for resistance to Fusarium wilt. Both varieties have been among those most susceptible to this disease in tests on both naturally infested and inoculated soil. There has been one exception; resistance was found in one plant of Punjab surviving in naturally infested soil of the Burns Field (11). Resistant progeny from this surviving plant were composited as a new variety, Punjab 53. The fact that Punjab 53 is resistant to clone 287 and 294 and resistant on naturally infested soil of the Burns field suggests that its resistance may be due to genes A and B. But because it is susceptible to wilt on the Goat Ranch, where clone 33–1 was obtained, it probably has no other genes for resistance. Studies are underway to verify this conclusion.

On the other hand it was rather surprising to find the variety Dakota to be a mixture of resistant and susceptible plants (11). Out of 174 selections, 26 or 14.9% were highly resistant. The resistance of these selections has appeared similar to that of Dakota 48–94 in this study, and has prevailed against all wilt clones in our tests. Sixteen of these resistant selections were composited to form the variety Dakota 52, and recommended for San Mateo County. The recommendation has been withdrawn, since Dakota 52, like Dakota, proved to be susceptible to flax rust (*Melampsora lini* (Pers.) Lev.) which appeared for the first time in San Mateo County in 1952. An effort will be made to learn whether or not all Dakota selections highly resistant to wilt have the same genes for resistance as Dakota 48–94. Susceptible selections of the same variety will also be studied to determine their similarity to Dakota 48–90. The variability in the genetic constitution of plants of the variety Dakota has emphasized the importance of basing genetic studies on products of crosses between single plants.

Equally as important as the selection of parents is the selection of the pathogen. When this study was in its earlier stages, clones 287 and 294 gave similar results (figure 1), and both gave data similar to that obtained from naturally infested soil (table 1). There was reason to believe that the choice of wilt clones did not matter too much, so long as other pathogens and insect larvae were excluded. Resistance seemed to be simply determined by the complementary genes A and B. The fact that these genes give no resistance to wilt clone 33–1 has forced a revision in this idea. At least a third gene and perhaps more are necessary for resistance to this clone.

While genetic studies will of necessity be limited to the use of only a few clones of wilt, it would be unwise to place the same limitation on tests of materials in a flax improvement program. There is need for the wilt plot infested with wilt as it occurs in commercial fields.

SUMMARY

The wilt-susceptible varieties Punjab (C.I. 20), Punjab 47 (C.I. 1115), and Dakota selection 48–90 were crossed with a selection of Dakota (C.I. 1071) termed Dakota 48–94. F_1, F_2, F_3, F_4 and backcross materials were grown on soil which was naturally infested with wilt or inoculated with one of three wilt clones.

Two complementary genes Fu_A and Fu_B—termed A and B for convenience—were found to be responsible for the resistance of Dakota 48–94 to wilt clones 294 and 287 and to the wilt of one naturally infested location. Punjab, Punjab 47 and Dakota 48–90 have the genotype aabb.

These complementary genes do not give resistance to the wilt of a second naturally infested location nor to wilt clone 33–1 obtained therefrom. Dakota 48–94 appears to have a major gene for resistance to this clone.

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Comparison of Original and Third Generation Sibbed[1] Seed-Stocks of S_1 Lines of Corn[1]

E. J. Wellhausen, Sterling Wortman, and Ernesto Peterniani[2]

IN THE Mexican Agricultural Program of The Rockefeller Foundation, S_1 lines of corn have been used extensively for the production of commercial double and three-way crosses. Two of the most important hybrids presently in production are combinations of S_1 lines which yield from 25 to 40% more than the open-pollinated varieties in their maturity classes. Although many hybrids developed from lines selfed four to five generations have been tested against these original combinations of S_1 lines, none has been found superior to the S_1 combinations in yield. For this reason, the use of S_1 lines for the production of commercial crosses has been advocated for those countries where new programs of corn improvement are being developed.

The use of S_1 lines for commercial crosses has been criticized to some extent by other investigators. Their arguments are: *(1)* that, because S_1 lines retain about 50% of the heterozygosity of their open-pollinated varieties, they are so variable and so vigorous that contaminants cannot be eliminated effectively in increase plots; and *(2)* that S_1 lines retain so much genetic variability that selection, whether natural or artificial, would be important in causing changes in the genetic constitution of the line.

The present study was designed to determine whether or not any of 28 important lines in the high altitude breeding program had changed through three successive generations of sibbings.

MATERIALS AND METHODS

Seed from the original first generation selfed ear of each of 28 lines was planted in 1950 and crossed with an unrelated tester. At the same time, third generation sibbed seed of each of these lines was planted and crossed with the same tester as its original counterpart. Each of these sibbed stocks had been increased through three generations, as follows:

For each generation 60 seeds were planted of each line in 2 adjacent rows. In the first row, 10 ear shoots were bagged before the appearance of silks and pollinated by a mixture of pollen from 10 plants in the second row. Although pollinators were told to pick plants at random, a certain amount of visual selection obviously took place, with a total of approximately 60 plants to choose from. At harvest, seed from the 10 plants was composited.

The 28 pairs of crosses were tested for yield in 1951 at the breeding station at Chapingo, Mexico, using a randomized block design in which the 28 pairs were planted together in paired plots and the paired plots distributed at random in each of 8 replications. During the season, data were taken on important agronomic characters and yield. The yield data were corrected for differences in stand and moisture, and were subjected to a standard analysis of variance. Also, the eight comparisons of the two seed stocks for each line were analyzed separately with the "t" test, both considering and ignoring the paired relationship in each replication.

[1] Journal Series Paper No. 20 of the Mexican Agricultural Program of The Rockefeller Foundation. Rec. for publication Oct. 21, 1954.

[2] Local Director, Geneticist, and former Latin American Scholar, respectively, with the Mexican Agricultural Program of The Rockefeller Foundation.

EXPERIMENTAL RESULTS

The 28 crosses involving original lines yielded an average of 15.53 kilograms per plot or 110.8 bushels per acre, while the 28 crosses of sibbed lines yielded an average of 15.62 kilograms per plot or 111.4 bushels per acre. The difference was not significant.

When the topcross yields for each pair of seed-stocks within lines were analyzed, using the "t" test, and the paired relationship was considered, nine significant or highly significant differences in yield were found, as shown in table 1. Of these nine differences only three were significant when the paired relationship was ignored. However, according to Fisher, "It sometimes occurs that one method shows no significant difference, while the other brings it out; if either method indicates a definitely significant difference, its testimony cannot be ignored, even if the other method fails to show the effect."[3] On this basis, therefore, 9 of the 28 lines appeared to have changed in combining ability; 4 showed losses and 5 showed gains.

A summary of the agronomic data obtained for the three S_1 lines Urq. 155, Urq. 130, and Qro. V-49, for which large changes in combining ability were observed, is given in table 2.

There were no important differences between top crosses of original or Sib_3 stocks for any of the agronomic characteristics on which notes were taken. This was true also for the other 25 lines. It was thought at the time of harvest that no changes had accompanied sibbing in any of the 28 lines.

DISCUSSION

Three years' mass-sibbing caused changes in the combining ability of several of the 28 S_1 lines. The five lines in which there was a significant gain in combining ability are considered to be "introduced" lines, since they were derived from introduced varieties not adapted to the Central Mesa where the sibbing was done. These gains might be attributed to selection for adaptation to Central Mesa conditions. However, the four lines in which losses occurred are also "introduced" lines, and the changes here might be due to contaminations and/or insufficient sample size in sibbing.

No visible differences could be detected between the topcrosses involving the original and Sib_3 stocks for any of the 28 lines, even where significant differences in yield were found. It must be assumed, therefore, that not all changes in combining ability or contaminations in S_1 lines can be detected visually.

Although composite sibbing was detrimental in only 4 of the 28 S_1 lines, it must be recognized, on the basis of these data, that the danger of detrimental changes through contamination or conscious or unconscious selection definitely

[3] Fisher, R. A. Statistical Methods for Research Workers. Tenth Ed. Oliver and Boyd, Edinburgh. 1948.

Table 1.—Mean yields in kilograms per plot for topcrosses of original and Sib$_3$ stocks of 28 S_1 lines of corn, their mean differences, and significance of the differences, as determined by the "t" test.

S_1 line	Stock	Mean yield Kg.	Mean difference† Kg.	Significance‡ P.	Significance‡ N.P.	S_1 line	Stock	Mean yield Kg.	Mean difference† Kg.	Significance‡ P.	Significance‡ N.P.
Urq. 130	Orig.	17.89				Qro. V–49	Orig.	14.70			
	Sib$_3$	16.51	−1.37 ± 0.47	*	**		Sib$_3$	12.70	−2.00 ± 0.35	**	**
Desc. 4–1	Orig.	17.07				Qro. V–185	Orig.	15.90			
	Sib$_3$	15.99	−1.09 ± 0.50	NS	NS		Sib$_3$	16.07	+0.17 ± 0.27	NS	NS
Qro. V–281	Orig.	15.62				Qro. VI–185	Orig.	13.16			
	Sib$_3$	16.70	+1.08 ± 0.38	*	NS		Sib$_3$	13.21	+0.05 ± 0.51	NS	NS
Qro. VI–366	Orig.	14.12				Urq. 97	Orig.	15.39			
	Sib$_3$	15.12	+1.00 ± 0.37	*	NS		Sib$_3$	16.20	+0.81 ± 0.32	*	NS
Urq. 104	Orig.	19.25				Urq. 66	Orig.	14.84			
	Sib$_3$	19.62	+0.38 ± 0.63	NS	NS		Sib$_3$	15.00	+0.16 ± 0.52	NS	NS
Urq. 124	Orig.	16.25				Qro. V-69	Orig.	14.59			
	Sib$_3$	15.52	−0.71 ± 0.30	*	NS		Sib$_3$	13.70	−0.89 ± 0.36	*	NS
Urq. 81	Orig.	16.16				Urq. 144	Orig.	17.46			
	Sib$_3$	16.64	+0.48 ± 0.62	NS	NS		Sib$_3$	17.84	+0.38 ± 0.43	NS	NS
Urq. 155	Orig.	14.10				Chap. I–54	Orig.	16.00			
	Sib$_3$	16.46	+2.36 ± 0.44	**	**		Sib$_3$	17.17	+1.17 ± 0.47	*	*
Qro. V–122	Orig.	13.12				Chap. IV–146	Orig.	15.62			
	Sib$_3$	13.95	+0.83 ± 0.40	NS	NS		Sib$_3$	15.60	−0.02 ± 0.66	NS	NS
Urq. 54	Orig.	16.37				Hgo. 1–5	Orig.	16.46			
	Sib$_3$	16.99	+0.61 ± 0.37	NS	NS		Sib$_3$	16.57	+0.11 ± 0.41	NS	NS
Qro. VI–595	Orig.	12.46				Hgo. 1–1	Orig.	15.76			
	Sib$_3$	12.53	+0.07 ± 0.16	NS	NS		Sib$_3$	15.74	−0.02 ± 0.43	NS	NS
Urq. 138	Orig.	14.85				Chap. IV–79	Orig.	14.64			
	Sib$_3$	15.05	+0.20 ± 0.59	NS	NS		Sub$_3$	14.72	+0.09 ± 0.25	NS	NS
Urq. 165	Orig.	14.22				Chap. II–148	Orig.	15.94			
	Sib$_3$	14.17	−0.05 ± 0.44	NS	NS		Sib$_3$	14.45	−1.49 ± 0.66	NS	NS
Urq. 56	Orig.	17.34				Chap. II–187	Orig.	15.47			
	Sib$_3$	17.54	+0.20 ± 0.55	NS	NS		Sib$_3$	15.65	+0.18 ± 0.52	NS	NS

† Average of individual differences between paired plots in eight replications. A positive mean indicates a gain in combining ability with sibbing. A negative value represents a loss.

‡ Significance values were determined by the "t" test, both considering the paired relationship (P) and ignoring it (N.P.)

* Significant at the 5% level.

** Significant at the 1% level.

Table 2.—Agronomic characteristics of original and Sib$_3$ stocks of three S_1 lines from the high altitude breeding program in Mexico, in which changes in combining ability probably accompanied mass sibbing.

Line	Stock	Rating* Ear	Rating* Mature plant	Rating* Green plant	Rating* Lodging	Rating* Broken plants	Rating* Rust	Height in meters Ear	Height in meters Plant	Days to flower
Urq. 155	Orig.	2.7	1.9	2.8	1.0	1.3	3.8	1.8	2.8	102
	Sib$_3$	2.7	1.9	3.1	1.0	1.1	3.8	1.9	2.9	102
Urq. 130	Orig.	2.3	1.1	2.4	1.0	1.0	3.1	1.9	3.1	103
	Sib$_3$	2.3	1.1	2.5	1.0	1.0	3.1	1.9	3.0	101
Qro. V–49	Orig.	2.5	1.6	3.2	1.1	1.1	4.0	1.8	2.9	100
	Sib$_3$	2.6	1.6	3.3	1.1	1.4	4.0	1.7	2.7	99

* On the rating scale used, 1.0 was considered excellent, 5.0 was poor. (Average of eight replications.)

exists and is probably much greater in S_1 lines than in more homozygous lines propagated through sibbing. However, S_1 lines have been successfully used in double cross hybrid production in the Mexican corn improvement program for the past 6 years. Perhaps this success is due in part to the methods used in propagating these lines, which are as follows:

1. The original S_1 seed is carefully increased up to 50 to 100 Kilos as rapidly as possible by hand sibbing under isolated conditions.

2. This seed is placed in cold storage at 8 to 10% moisture, which will maintain its viability over a relatively long period of time (10 years). Its combining ability is tested immediately and, if found as good as or better than the original, this seed serves as basic seed stock for future increase plots.

3. Isolated increase blocks are planted from this original, hand sibbed, basic seed-stock and propagated for 2 or 3 generations or until obvious changes appear. After contamination or changes are evident, the propagation plots are again planted with the basic seed-stocks in cold storage.

4. When it becomes necessary to increase the basic stock now in cold storage, it will be done carefully under isolated conditions and the new increase tested against the original to make sure it has not lost combining ability or other characters. S_1 lines are quite vigorous and seed increase is greatly facilitated thereby.

SUMMARY AND CONCLUSIONS

Original and Sib_3 seed-stocks of 28 S_1 lines of corn from the high altitude breeding program in Mexico were outcrossed to an identical unrelated tester. The topcrosses were tested for yield to determine whether or not any changes in combining ability had accompanied the three generations of seed increase through a composite sibbing technique.

Changes occurred in 9 of the 28 S_1 lines by 3 generations of composite sibbing. In five of the nine lines the changes were beneficial—the combining ability of the line was actually increased. In the remaining four, combining ability was decreased, probably because of unfavorable selection or contamination.

No visible differences in agronomic characteristics were detected between the original and Sib_3 topcrosses within S_1 lines, even in those cases where yield differences were significant and large.

A procedure for reducing possibilities of contamination or selection in the propagation and use of S_1 lines is presented.

Interspecific Hybridization of *Melilotus alba* x *M. Officinalis* Using Embryo Culture[1]

G. T. Webster[2]

SWEETCLOVER breeders have been striving for several years to develop productive strains which are free from or relatively low in coumarin. Following Smith's (8) successful transfer of genes for low coumarin content from *Melilotus dentata* to white sweetclover, *M. alba,* more rapid progress has been made toward this goal. The resulting low coumarin strains are all of the *M. alba* type, whereas there is considerable evidence that varieties of the yellow-flowered species, *M. officinalis,* are more drought tolerant and better adapted over much of the Great Plains Region.

Selection within strains and varieties of *M. officinalis* has failed to produce plants which are low enough in coumarin to be of use in a breeding program. Efforts to introduce genes for low coumarin directly from *M. dentata* have not been successful, since this species and *M. officinalis* appear to be completely incompatible even though their chromosome numbers are the same. Reciprocal crosses between *M. officinalis* and *M. alba* frequently result in a stimulation of ovule development, although viable seed from this cross has never been reported. Abortion of the ovules usually becomes evident within 8 to 10 days after pollination, and decomposition sets in by the 14th to the 15th day.

Examination of these ovules frequently revealed embryos which have become well developed before collapse occurs. It therefore appeared evident that low coumarin strains of *M. alba* might be successfully hybridized with *M. officinalis* through the use of embryo culture. Since success in the use of this technique with sweetclover has not been reported, a study of methods and nutrient materials was undertaken. A recent review of the literature pertaining to this subject was reported by Keim (4).

MATERIALS AND METHODS

The first medium to be used was basically Crone's modified nutrient solution which Parkey[3] found to be satisfactory in culturing buffalograss embryos. The stock salt mixture consists of the following:

KCl	10.0 gm.
$CaSO_4.2H_2O$	2.5 gm.
$MgSO_4.7H_2O$	2.5 gm.
$Ca_3(PO_4)$	2.5 gm.
$Fe PO_4$	2.5 gm.
$NH_4 NO_3$	2.5 gm.

[1] Contribution from the Agronomy Dept., Nebraska Agr. Exp. Sta., Lincoln, Nebr., in cooperation with the Fields Crops Research Branch, A.R.S., U.S.D.A. Published with the approval of the Director as paper No. 653, Journal Series, Nebraska Agr. Exp. Sta. Rec. for publication Oct. 21, 1954.

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[3] Parkey, Wade. Certain aspects of embryo culture and progeny evaluation in buffalograss. Unpub. Ph.D. thesis. Univ. of Nebraska, Library, Lincoln, Nebr. 1952.

The salts were ground to a fine powder and 1.5 gm. of the mixture added to 1,000 ml. distilled water with 0.6% agar and 2% sucrose. The solution was sterilized in glass vials for 15 minutes at 15 pounds pressure. The use of vials with cotton plugs was finally discontinued in favor of bottles with screw caps because of too rapid desiccation of the nutrient agar. Subsequently, other nutrient solutions were tried, including modifications of those recommended by Randolph and Cox (5) and by White (11). Different levels of sugar and agar concentrations have been studied and this work is still in progress.

Contamination of the sterile nutrient medium by microorganisms was held to a minimum by excising the embryos and transferring them to the vials under a transparent plastic hood which covered the microscope. The pyrex dishes in which the embryos were excised and the dissecting needles were frequently dipped in alcohol and flamed. Surface sterilization of greenhouse-grown seed pods was not necessary; but the use of material from the field resulted in a high frequency of contamination without this precaution.

The embryos were placed on or sometimes just below the surface of the medium and the vials were then kept in a diffused light until some further growth had occurred. At this time they were placed in full sun in the greenhouse. When the young plants had become well rooted, or had nearly outgrown the vial, they were transplanted into pots containing vermiculite and covered with a glass jar for 2 to 3 weeks. Nutrient solutions were added at weekly intervals. As the vermiculite settled, potting soil was added.

Embryos were removed from the ovules of selfed florets at various stages of development to determine the minimum size at which they could be cultured. At the same time, crosses were being made among several species, and the immature hybrid embryos from these were also transferred to the nutrient medium as they became available. At this time, the crossing program was concentrated on *M. officinalis* and *M. alba*, using Madrid and Common Yellow for the former, and low coumarin, finestem strains of *M. alba*. The latter had been developed from crosses between Wisconsin low coumarin strains and Nebraska finestem, green cotyledon types.

Quantitative coumarin determinations were made according to the revised fluorometric method outlined by Slatensek (7). A modified semiquantitative method was used for analyzing larger numbers of plants in segregating material. In this process, a small notch was removed from one of the younger leaves with fine-pointed scissors and placed in a 10 by 70 mm. glass test tube. Two ml. of normal NaOH solution were then added and the racks containing approximately 150 vials were heated in an autoclave for 20 minutes at 15 pounds pressure. The use of the autoclave and reduced concentration of NaOH appeared to produce the same effect as the previous method of adding 2.5*N* NaOH and heating for 2¼ hours in an Arnold steamer.

After cooling, the vials were examined with an ultraviolet lamp in a darkened room. This method serves only to identify the very low coumarin plants from those which show medium low to high content. The green fluorescence from those with approximately 0.5% is nearly as pronounced as that in plants having up to 2.0% or higher. Since plants with as little as 0.1% coumarin can usually be detected by this method, those which show no green fluorescence can be considered to be practically coumarin-free. In using this method, or any other, plants should be checked two or three times at different stages of growth.

RESULTS

Normal embryos, from self-pollination, excised at 15 or more days after fertilization could be propagated on most of the nutrient media used. At the earlier stages, the percentage of plants established from embryos was progressively lower, the minimum age being about 10 days. The search for a more suitable nutrient medium and better treatment methods for sweetclover embryos is still in progress. Results thus far have indicated that either the original nutrient medium given in "Materials and Methods" or that described by Randolph and Cox is as satisfactory as any which have been used. The ratio of plants established to the number of embryos excised is still too low, and it is believed that further work will provide a medium which will improve this ratio. The most significant improvement has been shown when the sugar concentration is increased from 2.0% to 4.0 or 5.0%. Concentrations as high as 10% have shown definite stimulation of root development although the tops have failed to make normal growth at this level. Rietsema, *et al.* (7) recently reported similar results in the culture of embryos of Datura. Results by others show that the growth of younger embryos was favored by the higher sugar concentration.

In attempting to cross *M. alba* and *M. officinalis*, a much higher percentage of ovule development resulted when *M. officinalis* was used as the pistillate parent. When the reciprocal cross was made, ovule development occurred less frequently and embryo growth was arrested at an earlier stage.

The hybrid embryos developed at a somewhat slower rate than those from self-pollination. Collapse of the ovules began to appear at about the 10th day following pollination, and the embryos usually ceased growth after the 11th to the 13th day. This was the optimum stage for excising, since deterioration set in soon thereafter and removal of the embryos without damage was difficult at the earlier stages. These observations are in agreement with the findings of Greenshields (2), who made histological studies of the embryo sac and the embryo at various intervals following cross-pollination.

Considerable plant-to-plant variation was shown with respect to the frequency of ovule development following cross-pollination. Certain plant combinations were completely incompatible, while others consistently resulted in a relatively high proportion of fertilized ovules. Likewise, the embryos from these crosses usually grew to a more advanced stage of development before abortion occurred.

F_1 Hybrids

Two *M. officinalis* × *M. alba* hybrids designated as No. 171 and 174 have been produced from embryo culture and reared to maturity. The pistillate parent of both hybrids was a single plant of the variety Madrid, and the pollen parents were low coumarin strains of *M. alba*. The hybrid plants were characterized by light green foliage and cream-colored flowers. Both showed approximately 75% stainable pollen and relatively high self-fertility. Their total growth under greenhouse conditions compared favorably with that of the parental types, although their rate of growth was slower.

A normal-green basal shoot, apparently the result of a somatic mutation in a crown bud, appeared on hybrid No. 171 soon after the plant flowered. This branch grew more rapidly than the original stem and likewise bore cream-colored flowers. Rooted cuttings from this branch showed the same dark green color and grew vigorously, while those from the original light green stem have been difficult to maintain. Plants from this dark green branch were designated as 171A.

Color of F_2 Seeds and Seedling Plants

Since the *M. alba* parents used in these crosses were green-seeded in contrast to the typical yellow or mottled seed color of *M. officinalis*, segregation appeared among the F_2 seeds produced on the F_1 plants. According to Fowlds (1), the green cotyledon character is inherited as a simple recessive, but the seed color is also influenced by the color of the somewhat translucent seed coats. Intraspecific crosses of green cotyledon × yellow cotyledon types made by this

Table 1.—F_2 seedling color and number of surviving plants from yellow and green seeds derived from interspecific hybrids *M. officinalis* × *M. alba*. 1953. Lincoln, Nebr.

F_1 hybrid No. and F_2 seed color	Color of seedlings and number of plants												Totals		
	Normal green			Light green			Pale green			Albino					
	Emerged	Survived	% survived	Emerged	Survived	% survived	Emerged	Survived	% survived	Emerged	Survived	% survived	Planted	Emerged	Percent emerged
171A															
Yellow	244	244	100.0	87	79	90.8	53	35	66.0	6	0	0.0	434	390	89.9
Pale green	133	133	100.0	33	31	93.9	28	20	71.4	2	0	0.0	216	196	90.7
174															
Yellow	300	297	99.0	917	616	67.2	351	48	13.7	29	0	0.0	1723	1597	92.7
Pale green	23	20	87.0	428	52	12.1	1458	0	0.0	5	0	0.0	2209	1914	86.6

writer have given good fits to a 3 to 1 ratio in the F_2 generation, and the F_3 progenies from green cotyledon types have produced only green seeds.

Classification of F_2 seeds of hybrids 174 and 171A was somewhat difficult because of the masking influence of the yellow seed coat. In many instances, before a seed could be properly classified, the seed coat had to be partially removed to expose the cotyledons. When this was done, cotyledons of a yellow-green color were frequently noted, the same color as is found in a high percentage of seeds of *M. officinalis*. Seeds with green cotyledons are described as pale green because of the yellow seed coats.

The ratios of number of pale green to yellow shown for the F_2 seeds of these two hybrids were distinctly different. In table 1, approximately 2 yellow seeds to 1 of pale green are shown from hybrid 171A, while hybrid 174 produced only 43.8% yellow seeds. The latter represents a random sample, while the former does not. From seed subsequently produced, counts showed a total of 2,640 yellow and 754 pale green seeds from hybrid 171A. This number approaches a 3 to 1 ratio, although the χ^2 value of 14 indicates a significant deviation from this ratio. A similar classification of 1,674 seeds from hybrid 174, however, again showed 690 yellow and 984 pale green or 41.2% yellow. It is therefore obvious that normal expected segregation for seed color did not occur on this hybrid plant.

The differences in color and the viability of seedling plants from these two hybrids were even more striking, as is also shown in table 1. Approximately one-half of either yellow or pale green seeds from hybrid 171A developed into normal green seedlings, the others being listed as light green, pale green, or albino, and these showed only a gradual reduction in viability from the normal green types to those with less chlorophyll. In contrast, among the seedlings from hybrid 174, only about one-sixth of those from yellow seeds were normal green, and from the pale green seeds, only 23 from a total of 2,209, or about 1%, developed into normal green plants. Furthermore, a very high rate of mortality occurred among those classified as light green or pale green. Only 12.1% of the light green, and none of the 1,458 pale green seedlings in this group survived. A lethal factor, associated especially with plants from green seeds, therefore appeared to have been present in hybrid 174 but not in 171A.

F_2 Flower Color

The intermediate cream color of the F_1 flowers and segregation in the F_2 generations were similar to that previously described in the white × yellow flowered interspecific hybrids, *M. alba* × *M. suaveolens* and *M. alba* × *M. polonica* (10).[4] Segregation for flower color among F_2 plants of both hybrids is shown in table 2. All plants were classified by visual matching of racemes with racemes selected to represent each of the five classes. Among the 122 plants from hybrid 174, ten were found to be as yellow as the *M. officinalis* species, but none was as white as *M. alba*. Even though a total of 413 F_2 plants from 171A were examined, neither of the parental types was recovered. Several of those

[4] Webster, G. T. Character inheritance, fertility relationships and meiosis in *Melilotus*. Unpub. Ph.D. thesis. Iowa State College Library, Ames, Iowa, 1949.

Table 2.—Segregation for flower color among F_2 plants from two hybrids, *M. officinalis* and *M. alba*. 1953. Lincoln, Nebr.

F_1 hybrid No.	Number of F_2 plants in each color class					Total plants
	Yellow	Dark cream	Cream	Light cream	White	
171A	0	30	295	88	0	413
174	10	24	71	17	0	122

Table 3.—Distribution of self-fertility scores of F_2 plants from two interspecific hybrids, *M. officinalis* × *M. alba*. 1953. Lincoln, Nebr.

F_1 hybrid No.	Number of F_2 plants in each class*					Total
	1	2	3	4	5	
174	8	31	16	10	0	65
171A	14	56	77	114	34	295

* Score 1 = highest fertility; 5 = lowest.

Table 4.—Fertility of interspecific F_1 hybrids backcrossed to both parental types. 1953. Lincoln, Nebr.

Reciprocal backcross	No. flowers pollinated	No. pods developed	Percent fertility
174 × M. officinalis	466	37	8.3
174 × M. alba	124	5	4.0
171A × M. officinalis	155	21	13.5
171A × M. alba	131	23	17.5

classified as light cream appeared to be white, but closer examination invariably showed traces of yellow, especially in the bud stage. This characteristic was not found on the flowers of *M. alba*. From these data it is evident that flower color in these crosses was determined by a minimum of three, and most likely more than three, factor pairs.

Self-fertility of F_2 Plants

No attempt was made to give numerical values to the degree of self-fertility of the F_1 plants, although both were more highly self-fertile than the mean value of any representative group of *M. officinalis* plants and approached that of *M. alba*. This self-fertility was also expressed in the F_2 population. Plants were selfed at irregular intervals by rolling the racemes between the thumb and first 2 fingers, and self-fertility scores from 1 to 5 were assigned to each plant when the seed pods had become well developed. Although rather crudely estimated, the distribution of self-fertility scores shown in table 3 indicate relatively high values among many of the F_2 plants.

Coumarin Content

Coumarin analyses of greenhouse plants tend to give lower and less reliable readings than plants making normal growth in the field. Also, readings of different plants taken at unequal stages of development may not be comparable, since the stage of growth has been shown to be a factor in total coumarin content (7). However, it has been observed that those plants which are making normal growth in the field or in the greenhouse, and showing consistently zero readings, usually produce progenies which are likewise low in coumarin.

From an analysis of the backcross progeny of hybrids between *M. Alba* and *M. dentata*, Smith (9) proposed 2 genes, the one reducing coumarin content from 2.5% to 0.5% and being recessive to high content, the other reducing the percentage to 0.1 with no dominance. He further suggested that the two genes acting together render plants coumarin-free.

Quantitative analyses of the 2 F_1 plants taken at the early bloom stage in the greenhouse showed hybrid No. 174 with 0.74% coumarin, and No. 171 with 0.17%. Both plants had one *M. officinalis* parent in common but different *M. alba* parents. None of the 493 F_2 plants from hybrid No. 174 were found to be low enough to give zero readings. However, among 462 plants from hybrid No. 171A, 80 which showed no coumarin with the short fluorometric method were saved for backcrossing to *M. officinalis*. This would suggest a single recessive major gene for low coumarin, although analyses of plants grown only in the greenhouse should not be accepted as being conclusive.

Results of Backcrossing with Respect to Self-Fertility

Both hybrids were reciprocally backcrossed to each of the parental species, with the results shown in table 4. Hybrid 171A again produced different results from that of hybrid 174, with a much higher percentage of seed set in relation to the number of flowers pollinated. This difference may have been due in part to the general lack of vigor of 174 compared with 171A. Selected low coumarin F_2 plants from 171A have also been successfully backcrossed to both parental species. Most of the resulting plants are vigorous and highly self-fertile.

Cytological Studies

Analyses of chromosome behavior at meiosis have not been completed, although smear preparations of pollen mother cells from the F_1 plants examined thus far have indicated a high degree of homology between members of chromosome pairs from the two species. This is to be expected, considering the high self-fertility. Some degree of abnormality is suspected, since at metaphase I two of the bivalents consistently appear to be in contact, usually at one end. Numerous cells have been observed in which six bivalents are apparently normal, but in all cases the other two appear to be attached. At anaphase I and prophase II, distribution of nine and seven instead of the normal eight and eight were occasionally observed. Excluded chromosomes and micronuclei have been noted in quartet stages, but not in sufficient numbers to account for the approximately 25% aborted pollen.

The morphological characters of one of the F_2 plants closely resembled those of tetraploid *M. alba* described by Johnson and Sass (3). The leaves were broader and thicker, with more prominent marginal serrations, and the floral parts were larger. Stomatal size was not determined, but the pollen grains were slightly larger and more rounded than the oval shape of the diploids. Only 5 to 10% of the pollen grains showed abortion, and the plant was highly self-fertile. Examination of pollen mother cells revealed chromosome numbers considerably higher than 16, although no accurate counts could be made. This plant was lost before a sufficient number of sporocyte samples could be collected for further study. Root tip smears from germinated selfed seed of this plant also showed a chromosome number approaching 32, and in a few instances actual counts of this number could be made. Five plants produced from selfed seed of this tetraploid all showed the same flower color, pollen size, and other morphological characters of the parent plant. This would indicate that the original F_2 plant and its progeny could probably be classified as amphidiploids.

DISCUSSION

Much work remains to be done to determine whether an improved nutrient medium for culturing sweetclover embryos can be developed. Also, it is not known to what extent the frequent growth failure of the excised embryos is due to the medium itself or how much can be attributed to damage to the embryo during the excising process. It is quite possible that both are contributing factors.

The F_2 data available at this time are not easily interpreted on a genetic basis. Even though meiosis of the F_1 plants appears to be reasonably normal, the 25% aborted pollen indicates that certain types of gametes are lost. If certain gametic recombinations are regularly eliminated as a result of some selective process, normal genetic F_2 ratios would not be expected to occur.

Observations made during this investigation further emphasize the necessity of utilizing large numbers of plants when interspecific hybridization is attempted. In many cases, where the range in variability of the available plant material is quite narrow, the possibility of obtaining such hybrids might be greatly enhanced through the introduction of new sources. The cross *M. messanensis* × *M. officinalis*, for example, has been found to result in a high frequency of apparent fertilization, since ovule development regularly occurred, especially when the former species was used as the pistillate parent. Numerous ovules have been examined, but in all cases the

embryos failed to develop to a stage where they could be expected to grow on the nutrient agar. *Melilotus messanensis* is highly self-fertile and little morphological variation has been noted in the material now on hand. It is not inconceivable that new sources of this species would provide greater opportunity to make this cross. Similar results might also be expected through the use of new sources of other species.

Since the cross-sterility barrier between *M. officinalis* and *M. alba* has been overcome through the use of embryo culture, other species crosses, previously thought to be impossible, should now be reconsidered. From the experience of this writer as well as other workers in this field, it is evident at this time that few, if any, additional species hybrid combinations can be made in the genus *Melilotus* without the use of this technique. All of the 20 to 25 species of *Melilotus* have been found to possess a somatic chromosome number of 16, but to date a total of only 12 species hybrids, including reciprocals, have been reported.[5] With the exception of the hybrids reported here, no other species is known to have been successfully crossed with *M. officinalis*. Some of the more uncommon species possess certain desirable characters which are lacking in the two now most widely grown species, *M. officinalis* and *M. alba*. For example, *M. taurica* has demonstrated a high degree of resistance to a serious sweetclover disease caused by *Ascochyta caulicola*. *Melilotus wolgica* is extremely susceptible to this disease, but its seeds germinate more rapidly, and seedlings emerge earlier from normal planting depths than those of any other known species in the genus. It is also believed that if the exceptionally large seed size of *M. messanensis*, *M. italica*, *M. sulcata*, or *M. speciosa* could be incorporated into economic species, it might be possible to obtain better stands under certain conditions by planting at greater depths. Hybrids with *M. messanensis* might be of additional value because of the low coumarin content of this species.

SUMMARY

Two fertile interspecific hybrids between *Melilotus officinalis* and *M. alba* were produced through the use of embryo culture. Previous attempts at hybridizing these two species have failed because of early abortion of the embryos. These crosses were made in an attempt to transfer low coumarin genes to *M. officinalis*.

The low coumarin character in the *M. alba* parents used in these crosses was originally derived as a result of hybridization of this species with *M. dentata*. Germplasm from three different species has therefore been incorporated into these two hybrids.

The foliage of the F_1 plants was light green in color with the exception of a normal green branch which occurred on one, presumably as a result of a somatic mutation. The flowers of both plants were an intermediate cream color.

The F_2 progenies showed segregation for seed and seedling color and for flower color. Low coumarin segregates were recovered from only one of the two hybrids. Both were successfully reciprocally backcrossed to the two parental species.

The low frequency of meiotic irregularity was insufficient to account for the approximately 25% aborted pollen on the hybrid plants. Normal F_2 segregation, however, appeared to have been disturbed.

[5] Report of the Fifth Sweetclover Improvement Conference, June 19, 1951.

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Differences Between Seed Lots of Ladino Clover in Cyanophoric Properties[1]

H. L. Portz and J. A. Jackobs[2]

THE Ladino clover seed certification program does not provide for limiting the number of generations that certified seed may be removed from a given source of seed. In the case of Ranger alfalfa and several other improved varieties of forages, certified seed is never more than three generations removed from breeder seed. Ladino seed from fields established with certified seed is eligible for certification. Under such a system any genetic changes that occur in a variety, whether they are due to natural selection or outcrossing, may become perpetuated and strains within the variety may arise.

LITERATURE REVIEW

The presence of cyanoglucoside in white clover was first reported by Mirande (10) and later identified by Melville and Doak (9) as consisting of 80% lotaustralin and 20% linamarin. The enzyme that hydrolyzes these glucosides, releasing free hydrocyanic acid has been identified as linamarase by Coop (2). Corkill (3) showed that individual plants could contain both glucoside and enzyme, glucoside only, enzyme only, or neither constituent. Williams (13), Atwood and Sullivan (1) and Corkill (4) all concluded that the presence or absence of the glucoside and the enzyme is determined by single dominant genes. Variation in the quantity of glucoside in different plants was ascribed to the effect of modifying genes.

The New Zealand Department of Agriculture has used a picrate test as a means of clover strain identification, following the investigation of Foy and Hyde (8). This test identifies plants that contain the cyanoglucoside and its hydrolyzing enzyme. The picrate-paper turns a reddish-brown when hydrocyanic acid is released following hydrolysis. Certified pedigree strains in New Zealand are uniformly high in cyanophoric properties[3] and the undesirable strains are low. Fifty 8-day-old seedlings are tested and the resulting color of the picrate-paper is compared to a set of standards. If the color is too light, the seed lot is rejected because of the contamination with undesirable strains of white clover. Corkill (5) has suggested that clover plants uniformly high in enzyme and without the glucoside be used. He found this clover to be equal in production to the strongly cyanogenetic New Zealand certified pedigree strain.

Ladino clover has been reported by Erith (7) to be acyanophoric, while wild white clover was found to be cyanophoric. Toniolo[4] reported that, of 25 Italian Ladino clover samples tested, none was cyanogenic. Sullivan (12) tested 635 clones of Ladino and only 13 gave a positive test for HCN. Of 400 seedlings from commercial seed, only 12 gave a positive test. This low frequency of cyanophoric properties in Ladino clover offers an opportunity for selection of noncyanogenetic plants, having neither glucoside nor enzyme, to be used as a source of breeder's seed in seed certification.

MATERIALS AND METHODS

Two hundred and thirty-five seed lots of *Trifolium repens* L. were tested to determine the frequency of the cyanogenetic glucoside and its hydrolyzing enzyme. The seed lots[5] represented the western seed-producing region, scattered locations in other parts of the United States, and some foreign countries. Approximately 80 seeds from each seed lot were planted in rows in flats of soil and grown in the greenhouse at Urbana, Ill., in 1952–1953. Samples from California, Idaho, Oregon, and Washington were represented in each flat when the certified Ladino clover seed lots were tested. From 20 to 32 seedlings from each seed lot were tested when there was a minimum of 3 to 4 trifoliolate leaves. A modified Guignard picrate-paper test developed by Corkill (3) was used. From 0.02 to 0.05 gm. (3 leaflets from each of the 3 trifoliolate leaves) of material was placed in each of 3 small culture tubes (1.0 cm. by 7.75 cm.). A drop of toluene was added to the first tube, toluene and a drop of prepared enzyme solution to the second tube, and toluene and a drop of glucoside preparation to the third tube. A picrate-paper strip (0.64 cm. to 6.3 cm.) was inserted in each tube and the tube was tightly corked. Color development in the first tube indicated the presence of both glucoside and enzyme in the clover seedling. The appearance of color in the second tube indicated glucoside, and color in the third tube indicated enzyme.

RESULTS

The results of this study show that the frequency of white clover plants with cyanophoric properties varies widely. Table 1 shows that an imported Italian Ladino seed lot had only

Table 1.—Number of seedlings with various cyanophoric characteristics in five seed lots of white clover.

Seed lot identification	No. of seedlings	Both glucoside and enzyme	Glucoside	Enzyme
Imported Italian Ladino	21	0	1	0
Louisiana Synthetic No. 1	21	21	21	21
Green Acres White Clover	21	19	19	20
Commercial White Clover Lot S	21	0	0	1
Commercial White Clover Lot T	21	0	1	0

Table 2.—Number of seedlings with various cyanophoric characteristics in four certified Ladino clover seed lots produced in Idaho.

Lot	No. of seedlings	Both glucoside and enzyme	Glucoside	Enzyme
187	30	0	0	0
191	30	1	5	1
554	30	2	7	17
E53	30	13	20	17

[1] Contribution from the Agronomy Dept., Illinois Agr. Exp. Sta., Urbana, Ill. Published with the approval of the Director of the Illinois Agr. Exp. Sta. Rec. for publication Oct. 21, 1954.

[2] Assistant, Crop Production and Associate Professor of Crop Production, Agronomy Dept., Univ. of Illinois.

[3] Cyanophoric properties refer to a cyanoglucoside and its hydrolyzing enzyme. A cyanogenetic plant is one having both constituents, thus releasing hydrocyanic acid.

[4] Toniolo, L. Contribution to the differentiation of the seeds of *Trifolium repens gigantum* (Ladino clover) from the *T. repens* (white clover). Unpublished paper prepared for 6th International Grassland Congress (not presented) 1952.

[5] The authors express their appreciation to E. A. Hollowell of the U.S.D.A., Beltsville, Md., for providing many of the samples used in this study.

1 plant out of 21 with the glucoside. In Louisiana Synthetic No. 1, all 21 plants contained both glucoside and enzyme. Commercial white clover seed lots from the Midwest contained plants with the cyanoglucoside or enzyme alone, but none with both.

Variations within Ladino clover derived from certified seed is shown in table 2. The frequency of plants containing both the glucoside and enzyme varied from 0 to 43% between seed lots obtained from one state, Idaho, and the occurrence of plants with the cyanoglucoside varied from 0 to 67%.

A graphic summary of the cyanophoric properties of Ladino clover plants derived from several lots of certified seed is shown in figure 1. The number of seedlings tested having both glucoside and enzyme is 2% of the 1,168 seedlings from Washington, 4% of the 1,622 from Oregon, 9% of the 699 from Idaho, and 15% of the 925 from California.

DISCUSSION

Differences in the frequency of plants with cyanophoric properties grown from certified Ladino clover seed lots have been demonstrated. They suggest the possibility that plants

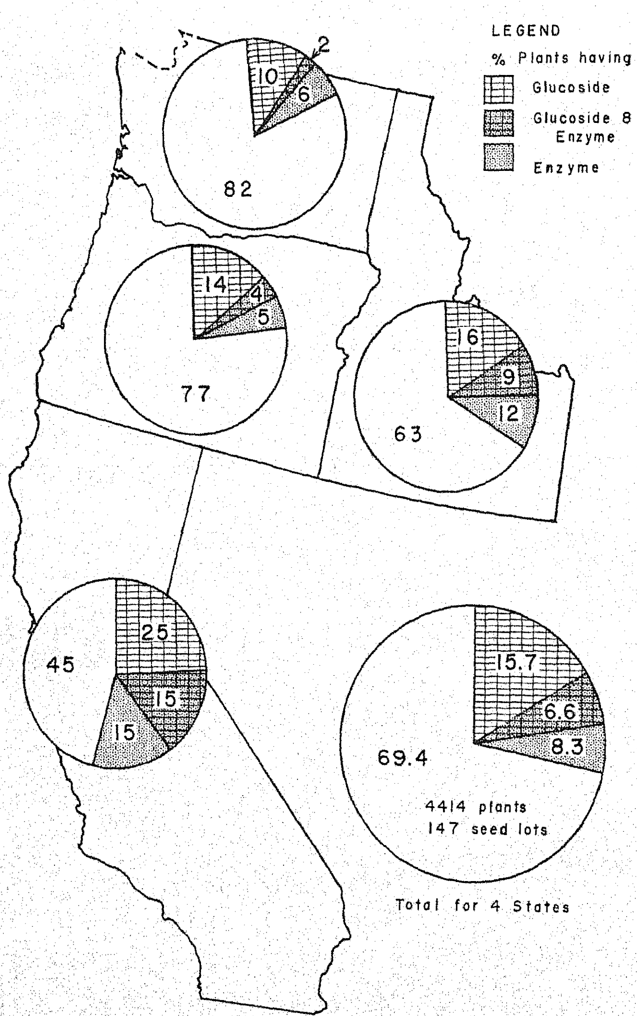

FIG. 1.—Summary of cyanophoric characteristics of certified Ladino seed lots from four of the Western seed-producing states.

may vary in other characteristics as well. Since one of the primary objectives of seed certification is to maintain genetic purity of a variety, the frequency of any gene in two different seed lots should be approximately the same. This wide variation in the gene frequency for glucoside and enzyme suggests that the present certification procedure for Ladino clover is inadequate.

There are at least three possible reasons for differences in observed frequencies:

(1) Original seed lots of Ladino clover have varied in their cyanophoric properties; *(2)* Shifts in gene frequency due to natural selection have taken place; *(3)* Outcrossing with other white clovers has occurred.

The frequency of cyanophoric properties in Italian Ladino clover has been shown to be very low. These samplings do not represent the seed lots from which the Ladino raised in the United States was derived. However, the findings would strongly indicate that original seed lots of Ladino clover were very low in the frequency of plants with cyanophoric properties.

The possibility that natural selection influenced the frequency of cyanogenetic plants in certain areas is strongly indicated. Ladino clover is considered to be a long-day plant. The latitude, in addition to the favorableness of temperature for early flowering, varies considerably from California to Washington. If plants with cyanophoric properties blossomed earlier than acyanophoric plants when under a short-day length, such as occurs in California and other southern states early in the growing season, a considerable genetic shift might occur in a few years. Southern types of white clover, such as Louisiana Synthetic No. 1, are highly cyanogenetic. Recently Daday (6), in a study of gene frequencies in wild populations of white clover, found a progressive increase in the frequency of recessive genes for glucoside and enzyme in moving from southern to northeastern Europe. The dominant glucoside gene frequency decreased 4.23% and the enzyme gene frequency by 3.16% for each reduction of 1° F. January mean temperature.

Outcrossing with other white clover types must certainly be considered. All white clovers are readily cross-pollinated by bees; thus, any white clover growing in the vicinity of Ladino seed-producing fields is a ready source of contamination. Fortunately, many western seed-producing areas are on newly irrigated land with little white clover growing in the region. Tests of white clover have shown some seed lots to be primarily free of cyanogenetic plants. However, samplings of wild-growing clovers have shown from 7 to 80% of the plants with cyanophoric characteristics.

The certification program for Ladino clover should be modified to minimize genetic shifts such as those reported in this paper. If a source of breeder seed is established, a limited generation system could be followed similar to that in Ranger alfalfa.

Selection of plants having neither glucoside nor enzyme could be readily accomplished. Contamination with glucoside and/or enzyme could be easily detected by a simple picrate test run in collaboration with the germination test. In addition, "glucoside" or "enzyme" contamination is easier to detect than the dilution effect from a low frequency of these two characteristics, the process now employed in New Zealand.

SUMMARY

Ladino and other white clovers were tested for their cyanophoric properties by a modified picrate-paper test. The frequency of plants containing the cyanoglucoside varied from 0 to 67% between seed lots of certified Ladino clover. There was a range of 2 to 15% in the number of cyanogenetic plants from seed lots obtained from the different western states producing commercial seed.

Three possible reasons for these differences were suggested: *(1)* Original seed lots have varied; *(2)* Natural selection has taken place; *(3)* Outcrossing with other white clovers has occurred.

Variations in the frequency of Ladino clover plants with cyanophoric properties have been demonstrated. Such variations indicate a need for an improved certification procedure.

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Notes

THE DETERMINATION OF MACRO-ORGANIC MATTER IN SOILS[1]

THE term macro-organic matter is introduced to denote coherent particles of organic matter separated from the soil by screening and decantation procedures. Such separates have been variously termed "underground yields" by Shively and Weaver (6), "roots and other plant residues" by Saharina (4), "root fibre" by Stevenson and White (7), and "underground plant materials" by Troughton (8).

Washing and screening methods have been described by Goedewaagen (2) and Jacques (3). Soil cores were thoroughly wetted by soaking, then washed on top of a wire or horsehair screen of *ca.* 0.5 mm. aperture. Macro-organic matter was separated from the sand residue by washing in and pouring from shallow dishes onto a screen or baffle. Large clumps of organic debris were usually removed with tweezers. Salonen (5) ashed the separate obtained by washing and screening, and determined the weight of ash-free material. These methods were tedious, five to ten samples being determined per man day, and were liable to personal error.

Barley (1) used a flotation method, in which macro-organic matter was separated by centrifugation of crushed samples suspended in salt solutions of density 1.2 gm. per ml. The separate was decanted onto a filter, washed with water and oven dried. This method was relatively rapid (20 determinations per man day), but it exposed expensive centrifuge equipment to corrosion, and efficiency of recovery was variable (80 to 100%).

[1] Experiment conducted at the Agronomy Department, Cornell University, by the author while on leave from Commonwealth Scientific and Industrial Research Organization, Deniliquin, Australia. The author wishes to acknowledge the helpful advice given by Dr. R. D. Miller. Rec. for publication March 29, 1954.

Attempts were made to separate macro-organic matter by simple elutriation of dispersed samples, the effluent being passed through a screen of 0.25-mm. aperture. The settling velocity of sand just retained by the screen (3 cm. per sec.) exceeded the settling velocity of 95 to 99% of water saturated clean macro-organic matter particles, but in practice sand particles adhered to the macro-organic matter preventing reasonably efficient separation by elutriation.

PROCEDURE

The procedure described below involves dispersion of the sample followed by stirring and decantation. The stirring action frees the macro-organic matter from adhering sand particles, and reduces the settling velocity of the oblong macro-organic matter particles relative to that of the sand particles. The method is fast (30 samples per man day), efficient and reproducible.

1. Crush a bulk sample to pass a 5 mm.-aperture screen, using a rubber tipped pestle or rubber roller. Allow the soil to air-dry, then cut roots into lengths not exceeding 1 cm., using a bank of circular knives mounted on an axle at 5-mm. intervals. Thoroughly mix the sample then withdraw a 50-gm. subsample for macro-organic matter determination, and one 50-gm. subsample for soil moisture determination. Weigh each subsample to the nearest 0.5 gm.

2. Soak a 50-gm. subsample of air-dry soil for 60 minutes in 10 ml. of "Calgon" solution (200 gm. per l.) plus 100 ml. of water.

3. Transfer to a dispersion cup, three-quarters fill with water, and stir for 5 minutes with a Bouyoucos high speed stirrer. Allow the suspension to settle for 30 seconds before decanting onto a 0.25-mm. aperture wire sieve of *ca.* 7 cm. diameter. If any aggregates remain, refill the cup with water and stir for a further 5 minutes before again decanting. Repeat until all aggregates have been dispersed, then transfer the remaining contents of the cup to the screen.

4. Transfer the residue on the screen to a cylindrical beaker of 8-cm. diameter and fill to a depth of 10 cm. Stir with a rectangular spatula at three revolutions per second for 15 seconds, then withdraw the spatula without interrupting its revolution. Pause for 5 seconds, then decant gently onto a clean 0.25-mm.

screen, allowing 15 seconds for decantation. Refill the beaker and repeat the stirring and decantation procedure three times.

5. Wash the macro-organic matter separate on the screen with 500 ml. of water, delivered from an orifice of 2.5-mm. diameter at 10 ml. per sec.

6. With the aid of a wash bottle, transfer the separate to a labelled filter paper held under suction on a Buchner funnel. Fold the paper and dry over night at 60° C. Cool in a dessicator, then quickly transfer the macro-organic matter to a tared aluminum dish and weigh to the nearest 5 mgm.

7. Calculate the mass of dry macro-organic matter (60° C.) per 100 gm. of oven-dry soil.

Efficiency of Macro-Organic Matter Recovery

Losses of macro-organic matter occur due to solution, passage of fine material through the screen, and failure of a few dense particles to remain in suspension during decantation. Error due to adhesion of soil particles to the macro-organic matter does not compensate for these losses.

Data on the efficiency of recovery were obtained using air-dry macro-organic matter which had been hand separated from sandy soil supporting an old stand of *Festuca rubra* L. The particles were cleaned by striking them repeatedly against a glass plate, until they were freed from adhering sand. Long particles were cut into lengths less than 1 cm.

Loss due to solution.—Triplicate 0.2-gm. samples of macro-organic matter were weighed air-dry, separate samples being taken for determination of moisture content. The triplicate samples were soaked in 10 ml. of "Calgon" solution and 100 ml. of water for 60 minutes, and were then transferred quantitatively to a filter paper held under suction, washed with 2 l. of distilled water, oven dried at 60° C. and weighed. Mean loss due to solution equalled 5.6% of original oven-dry weight.

Loss due to screening.—0.2 gm. samples of macro-organic matter were weighed air-dry, separate samples being taken for determination of moisture content. Duplicate samples were soaked in "Calgon" solution and water, then washed on each of a range of screens with 2 l. of water delivered as in step 5 of the separation method. The residue on each screen was recovered as in step 6. Table 1 shows the mean loss of macro-organic matter per cent of original oven-dry weight for the range of screen apertures.

Mechanical breakdown of macro-organic matter during dispersion of soils in the Bouyoucos stirrer may lead to greater losses during screening than are recorded in table 1. To allow for an increase in the proportion of fine material, the 0.25-mm. screen has been employed in the separation method. The practice of decanting after each 5 minutes of stirring removes most of the macro-organic matter from the stirrer-cup at an early stage of dispersion and reduces mechanical breakdown. The soaking time should not be increased beyond 60 minutes in an attempt to reduce the time of stirring, since flotation of the macro-organic matter is reduced as the degree of water saturation increases.

Overall efficiency.—Known weights of air-dry macro-organic matter were wet mixed with 50-gm. lots of quartz sand and of kaolin clay, which had been moistened with 0.2% mercuric chloride solution. Separate samples of macro-organic matter were taken for determination of moisture content. The mixtures were allowed to air-dry, and the macro-organic matter was then separated by the method described above. Triplicate determinations of percent recovery of macro-organic matter were made at each of three concentrations. Results are shown in tables 2 and 3.

Table 1.—Percent loss of oven-dry M.O.M. due to screening.

Screen aperture	Total loss of M.O.M.	Expected loss due to solution	Loss due to screening
mm.	%	%	%
0.10	5.6	5.6	0.0
0.25	5.6	5.6	0.0
0.50	6.1	5.6	0.5
1.00	11.9	5.6	6.3

Table 2.—Percent recovery of M.O.M. from sand.

Oven dry mass of added M.O.M. gm/100 gm.	Oven dry mass of recovered M.O.M. gm/100 gm.	Percent recovery of total M.O.M.	Percent recovery of insoluble M.O.M.*
0.000	0.001†	—	—
0.013	0.013	100	105
0.098	0.091	94	99
0.978	0.881	90	95

* Allowing 5% loss due to solution.
† Fine sand.

Table 3.—Percent recovery of M.O.M. from clay.

Oven dry mass of added M.O.M. gm/100 gm.	Oven dry mass of recovered M.O.M. gm/100 gm.	Percent recovery of total M.O.M.	Percent recovery of insoluble M.O.M.*
0.000	0.000	—	—
0.011	0.010	93	98
0.099	0.087	93	98
0.974	0.870	88	93

* Allowing 5 per cent loss due to solution.

The presence of a small amount of fine sand in the separate caused a positive error at low concentrations, but losses due to solution, screening and inadequate flotation predominated at high concentrations causing a negative error. The negative error increased with concentration in both series. Triplicates agreed to within 2% recovery at intermediate and high concentrations.

The method of macro-organic matter separation described is rapid and reproducible. The efficiency of recovery declines with increase in concentration of macro-organic matter.—

K. P. BARLEY, *Regional Pastoral Laboratory, N. S. W., Australia.*

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TILLERING AND YIELD OF OAT PLANTS GROWN AT DIFFERENT SPACINGS[1]

THE extent of tillering is one of the factors affecting grain yields in cereals. To study the association between tillering, yield, and plant height, an experiment was conducted in 1950 and 1951 with the oat varieties Otoe, Clinton, Cherokee, Nemaha, and Marion. Stand density was controlled by spacing plants 2.5 and 5.0 inches apart in 7-inch rows. At maturity, plants were pulled and the number of grain-bearing and total tillers, height, and yield per plant were determined. Plant height was taken on the tallest tiller by measuring the distance from the uppermost node showing crown roots to the uppermost spikelet of the panicle. The rusts were minor diseases both years.

Highly significant differences were recorded in the average number of productive tillers between spacings within varieties. Otoe developed the largest number of productive tillers in both years and spacings. Clinton was the lowest tillering variety in both seasons. The early varieties Otoe, Nemaha, and Cherokee produced grain on 88% of all tillers formed while the later maturing varieties, Clinton and Marion, bore grain on 63 and 56%, respectively, of the total number of tillers developed on plants at the 2.5-inch spacings. However, the average total number of tillers formed was as great for late as for early varieties. Varietal differences in tiller number were less in the 5-inch than in the 2.5-inch spacing.

At the 2.5-inch spacing, regression of yield on number of tillers expressed in grams per tiller was within the range from 0.824 to 1.155 as recorded for Otoe and Nemaha, respectively. At the wider spacing, the corresponding values were 1.117 for Otoe and 1.580 for Clinton.

The intra-varietal comparisons within spacings indicated a positive association between tillering and plant height. This association was smaller under the wider spacing.

Coefficients of correlation between plant height and yield were determined for each tiller class within both spacings. Highly significant positive values were obtained in most of the tiller classes for each variety. For the modal class of 3 tillers per plant, *r* values ranged from 0.491 to 0.622 at the 2.5-inch spacing and from 0.34 to 0.841 at the 5-inch spacing.

Based on the varieties grown over the 2-year period, 75% more grain was produced under the 5-inch spacing than under a spacing of 2.5 inches. The data indicated that 77% of the total yield increase in the widely spaced plants resulted from increased tillering, 16% from increased yield per tiller, and 7% from the interaction of both factors.—KARL KAUKIS, *Assistant in Agronomy, Nebraska Agr. Exp. Sta., and* L. P. REITZ, *Senior Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A., Lincoln, Nebr.*

[1] Rec. for publication Oct. 20, 1954.

INHERITANCE OF A WHITE FLOWER COLOR IN CRIMSON CLOVER, *Trifolium incarnatum*[1]

ALTHOUGH several improved varieties of crimson clover are now available for use by farmers, they cannot be readily identified by plant characteristics. White-flowered plants often occur in stands of crimson clover, and if this characteristic could be utilized as a marker, varietal identification in the field would be simplified. Consequently, a study to determine inheritance of white flower color in common crimson clover might be helpful in a breeding program.

During the winter of 1952, 106 plants were grown in the greenhouse from open pollinated seed of a white-flowered plant found in a stand of common crimson clover. Seventy plants were white and 36 were red flowered. Occurence of red flowered progeny indicated outcrossing and suggested that red was dominant to white flower color. White-flowered plants undoubtedly resulted from natural selfing. On the basis of this assumption, red-flowered plants were assumed to be heterozygous and white-flowered plants homozygous recessive for flower color. Self-fertilized heterozygous plants should then segregate and homozygous recessive plants should breed true for flower color. To study the inheritance of flower color, eight pairs of red and white flowered plants were selfed and reciprocally crossed by hand. Seed of the F_2, S_2 and reciprocal backcross generations were planted in the greenhouse in the fall of 1953.

Data for flower color in the F_2, S_2 and reciprocal backcross populations are given in table 1. The segregation of flower color in the F_2 from heterozygous red F_1 plants gave a satisfactory fit to a ratio of 3 red to 1 white-flowered plants. This demonstrated that red flower color was dominant to white in F_1 and that inheritance in F_2 was simple. Since the S_2 plants from white-flowered parents bred true for flower color, the homozygous recessive can be assumed to condition white flower color.

Table 1.—Frequency distribution for flower color in F_2, S_2 and reciprocal backcross populations of crimson clover.

Generation	Flower color		Ratio	Chi ^{2}	P
	Red	White			
	Number				
F_2	109	29	3:1	1.169	.20–.30
S_2	—	26	—	—	—
BC	29	34	1:1	.396	.50–.70

The segregation in the reciprocal backcrosses to the white flowered plants gave a close fit to a 1:1 ratio thus substantiating the assumption that one factor pair was involved in the expression of flower color.

The symbols, Cr, cr are suggested for this pair of alleles with the dominant gene necessary for red flower color and the recessive allele conditioning white flower color.

True breeding white-flowered types have been isolated, and plans are underway to develop a variety uniform for white flower color. The white-flowered types appeared as

[1] Research paper No. 1131, Journal Series, University of Arkansas, Fayetteville, Ark. Published with the permission of the Director of the Arkansas, Agr. Exp. Sta. Rec. for publication Nov. 5, 1954.

vigorous as red-flowered types in the greenhouse. Since the several varieties of crimson clover now available cannot be readily distinguished in the field by plant characteristics, a white flowered strain would greatly facilitate field inspection for seed certification. Growers also could effectively maintain varietal purity by roguing red-flowered plants prior to pollination in seed fields. Too, a white flower marker gene would be helpful to determine effective hybridization in a crossing and breeding program and aid in other genetic studies with crimson clover.—P. C. SANDAL, *Associate Agronomist, North Dakota Agr. Exp. Sta., formerly Assistant Agronomist, Arkansas Agr. Exp. Sta.*

Book Reviews

PLANT ANALYSIS AND FERTILIZER PROBLEMS

Edited by P. Prevot. A symposium. Prof. H. Lundegardh, chairman. Eighth International Botanical Congress, Paris, France, July, 1954. I.R.H.O. Paris, France. 263 pp. illus. 1955. $4.00.

This volume is a collection of prepared papers presented at a symposium organized by the Institut de Recherches pour les Huiles et Oleagineaux and under the auspices of the 8th International Botanical Congress. The informal discussions and debates following the presentation of each paper are also presented.

Papers dealing with some of the fundamental physiological relations of plant composition to growth and yield are presented by H. LUNDEGARDH (Sweden), F. STEENBJERG (Denmark), A. ARLAND (E. Germany), T. WALLACE (England) and O. BIDDULPH and A. S. CRAFTS (U.S.A). A second group of papers concerning plant and analysis methods is presented by R. L. MITCHELL, D. NICHOLAS (British Isles) and A. W. SPECHT, P. F. SMITH and J. W. RESNICKY (U.S.A.). A third group is concerned with the application of plant analysis techniques to fertilization problems. Authors contributing to this group are J. CARLES, S. TROCME, J. FR. de FERRIERE, P. HALAIS, A. LOUE, P. PREVOT and M. OLLAGNIER, M. FERRAND and J. F. LEVY (France and its colonies), L. HERSHBERG and R. M. SAMISH (Israel), C. TAMM (Sweden), W. S. ILJIN (Venezuela), M. L. SALGADO (Ceylon), M. DROSDOFF, J. L. HADDOCK, W. REUTHER and P. F. SMITH (U.S.D.A.). Applications of plant analysis to such diverse crops are coconut, coffee, citrus, tung, grapes, deciduous fruits, wheat, sugar beet, sugar cane, oil palms, peanuts, and others are considered.

This volume is the record of the first international symposium dealing with the fundamentals, techniques and applications of plant tissue analysis methods to problems of fertilization of plants. It is evidence of the growing body of literature on this subject, the increasing number of workers interested in this field, and the value of this approach in evaluating the mineral nutrient requirements of crop plants. No worker interested in soil fertility and mineral nutrition problems of plants will want to be without this valuable group of references.—WALTER REUTHER.

PERSPECTIVES AND HORIZONS IN MICROBIOLOGY

Edited by Selman A. Waksman. A symposium. Rutgers University Press, New Brunswick, N. J. 220 pp. 1955. $3.50.

This symposium of scientific papers written by 13 eminent bacteriologists commemorates the dedication on June 7, 1954 of the Institute of Microbiology, Rutgers University. Dedication addresses by LEWIS WEBSTER JONES, President, Rutgers University; SELMAN A. WAKSMAN, Director, Institute of Microbiology, and ALBERT J. KLUYVER, Professor of Microbiology, Technical University, Delft, Holland, highlight the volume.

The scientific papers are exceptionally well written and, in keeping with the title of the volume, cover a wide range of topics. The papers by CORNELIS B. VAN NIEL, ANDRÉ LWOFF, JOSHUA LEDERBERG, and BERNARD D. DAVIS deal with the microbe as a living system. The subject of microbial metabolism is contained in five papers by H. A. BARKER, JACKSON W. FOSTER, WAYNE W. UMBREIT, PERRY WILSON, and DUREY H. PETERSON. Four papers by MICHAEL HEIDELBERGER, FRANK L. HORSFALL, JR., HARRY EAGLE, and ROBERT L. STARKY concern microorganisms and higher forms of life. The readability of these papers is enhanced by their brevity and clarity in presentation.

As a brief presentation of the many-sided aspects of microbiology, the volume is not only a worthwhile contribution to the reading list for graduate students, but also a valuable aid to the more mature professional bacteriologist. The reference sections of the papers are comprehensive and evidence the broad scope of the various subjects. Perhaps the major shortcoming of the volume is its paucity of illustrations. Only one paper contains half tone reproductions. It is in this vein of thought that this reviewer feels the volume will likely evoke some disappointment, since such an excellent opportunity existed to depict photographically the Institute and the contributors, as well as the various aspects of the dedication ceremonies.—O. N. ALLEN.

AN INTRODUCTION TO PLANT TAXONOMY

By George H. M. Lawrence. The Macmillan Co. New York. 179 pp. 1955. $3.25.

This book by the director of the Bailey Hortorium at Cornell University, is written for the adult amateur botanist and for the student of a local flora course at the college level. It is restricted to ferns, conifers and other gymnosperms and flowering plants, and the author has drawn much from his earlier book, *Taxonomy of Vascular Plants* (1951) in this presentation. In defining the subject of taxonomy, the author emphasizes its fundamental importance to all biological science and to an understanding of the natural resources of the world. Chapter headings include Plant Classification, Evolution and Units of Classification, Plant Structures, Collecting and Identifying Techniques, Nomenclature, Phylogeny and Biosystematics, Taxonomy in North America, Important Families and Their Characters, and a combined glossary and index.

The chapter on plant structures takes up the morphology and terminology peculiar to each group of the vascular plants—the ferns and lycopods, the gymnosperms and the angiosperms. Chapter 8 presents an interesting historical review of taxonomy in North America, and Chapter 9 presents the distinguishing characters of some 50 of the more dominant families of vascular plants. The student or amateur who has had an introductory course in botany will find this excellent, compact volume of great help. It is applicable to any part of North America.

AGRICULTURAL PROCESS ENGINEERING

By S. M. Henderson and R. L. Perry. John Wiley & Sons, Inc. New York. 402 pp. 1955. $8.50.

This textbook should be a great aid in teaching agricultural processing to advanced students in agricultural engineering. It is the only book known to this reviewer that covers the agricultural processing field so completely.

There are only a few universities now offering an agricultural engineering curriculum with advanced courses in agricultural processing. However, it appears that the processing of agricultural products will be of increasing importance in the future. Employment in commercial processing plants should be good for agricultural engineering graduates.

Some of the information in the book is a duplication of other courses which an engineering student would take in his regular curriculum. It is probably well to have this repetition, however, as many students may not have these engineering courses.

The material on drying, evaporation, and dehydration is very good. This field of processing is one that is developing rapidly. The drying and dehydrating of farm products appears to be one practical method of preserving farm produce for use on the farm

as well as for shipping for commercial use. Training in this field certainly should be important.

One phase of processing on which more information could have been given would be the freezing of farm products. This method of handling farm produce for human consumption is probably expanding more than any other method of preservation. It is impossible, however, to cover the broad field of agricultural processing in one volume. The authors have done a good job in preparing this textbook to give the student a wide coverage of the field.—L. A. BROOKS.

MARKETING AGRICULTURAL PRODUCTS

By Richard L. Kohls. The Macmillan Co., New York. 398 pp. 1954. $5.25.

In the final analysis, the most industrious application of the best agronomic practices will mean little without a marketing system that functions fairly and equitably for both the farmer and his customer. Prof. Kohls of Purdue University has written this textbook for beginning students in farm marketing. It is a well-documented presentation which uses three general approaches to a survey of this broad, complex field. As developed in three main parts of the book, they are: "The Framework of the Marketing Problem," which defines the general terms of marketing, production, consumption; "Functional Problems," which discusses pricing, competition, government aid in marketing, importance of standardization, collection and use of market information, transportation, storage, and commodity speculation; and "Commodity and Institutional Problems," which presents the problems of particular commodities and markets. This section also contains good discussions of farm cooperatives, marketing regulations, the food processing industry, and the wholesaling and retailing of food.

Strong emphasis is put on the dynamic aspects of consumption and the adjustments which production and marketing must make to meet the changing needs of the vast consuming public. The author also stresses the need for an enlightened consumer public.

The possibilities of advertising farm products are also considered, and the author points out that "the stomach is only so big," and "customers tend to spend a rather constant percentage of their incomes on food."

It would be great help if such general textbooks as this could somehow be offered in digest form to the general public. To the average housewife, nothing is more prosaic, tedious and important than the weekly grocery order. Yet nothing is more taken for granted than well stocked grocery shelves; and nothing is more irritating than to find a favorite item missing from the shelf. Although a textbook, this book could well be read by anyone.

STANDARDS FOR A STRONG AMERICA

Proceedings of the Fifth National Conference on Standards and the Thirty-sixth Annual Meeting of the American Standards Association, New York. November 1954. $3.00.

Of particular interest to agricultural workers in this volume is the Symposium on Standards for Agriculture. The following papers were presented in this symposium: Seed Quality Factors and Seed Standards, by B. E. CLARK, head of the Department of Seed Investigations, N. Y. State Agricultural Experiment Station, Geneva; Establishment of Common Names for Pest-Control Chemicals, by HERBERT L. HALLER, assistant director of Crops Research, ARS, USDA, Washington, D. C.; The International Standards Problem on Common Names for Pest-Control Chemicals, by J. E. ARCHER, director, Patent Division, American Cyanamid Co., Stanford, Conn.; Standards for Nursery Stock, by RICHARD P. WHITE, executive secretary, American Association of Nurserymen; and Development of Uniform Standards for Florists' Cut Flower Crops, by HAROLD BROOKINS, chairman of the Grading Committee of the N. Y. State Flower Growers, Inc.

Dr. Clark explained the seed-certification program of New York State and pointed out that measurement of seed quality is a difficult and complicated procedure. Dr. HALLER discussed the need for simplification in common names for pest-control chemicals, and listed some of the dangers inherent in the use of numbers and letters as abbreviated names.

Other fields covered in this volume are the electrical industry, color television, safety standards, and modular coordination. A section is devoted to discussions on the future of standardization. Many general readers will find in these Proceedings a new insight into some of the problems and challenges which face American industries.

MULTILINGUAL VOCABULARY OF SOIL SCIENCE

Edited by G. V. Jacks. Published by the Agriculture Division, Food and Agriculture Organization of the United Nations. 439 pp. 1954.

Soil scientists will welcome this lexicon which is one of the series of FAO publications designed to meet the needs of agricultural workers throughout the world. Many workers know the difficulties of translating technical terms, and the barrier which this creates to any easy exchange of soils information among various countries. Hundreds of technical terms are listed in the eight languages, English, French, German, Spanish, Portugese, Italian, Dutch and Swedish. The terms are grouped according to subject as follows: physics, texture and structure, soil water, chemistry, organic matter and humus, biology and ecology, cultural practices, soil formation and morphology, profile characters; geology, topography and climate; mineralogy, classification, organic and peat soils, Podzolic soils, gley and meadow soils, arid and semi-arid soils, saline and alkali soils, tropical and sub-tropical soils, intrazonal and azonal soils; terracing, damming and drainage; irrigation, and erosion. Each page of the glossary lists a separate term in each of the eight languages. To locate a word in the glossary, the reader must refer to one of the eight alphabetical indexes at the back of the book. This vocabulary was started in 1949 by Dr. H. Greene and was reported at the 4th International Congress of Soil Science in Amsterdam in 1950. The present volume resulted from additions and modifications suggested by national nomenclature committees and others following the report at Amsterdam. All who participated in the preparation of this work, are to be commended for the tremendous amount of work necessary to such a task. The fact that many terms have different shades of meanings in different languages was only one of the hurdles to overcome. The result should be gratifying to the contributors and to all who use the book.

COMMERCIAL FERTILIZERS, THEIR SOURCES AND USE

By Gilbeart H. Collings, McGraw-Hill Book Co., Inc. New York. 617 pp. 1955. $8.00.

This is the fifth edition of the standard reference on commercial fertilizers which first appeared in 1934. The great advances made in agronomic research in the past generation have imposed upon educators the burden of keeping students, farmers and farm advisors informed on the newest technological developments and practical applications. The student or farmer is quite likely to find here a good answer to almost any general question on commercial fertilizers. Extensive revision brings to the reader the wealth of recent research in plant nutrition which underlies a great part of the newest fertilizer developments.

Following an introductory chapter on the origin and development of commercial fertilizers, succeeding chapters deal separately with sodium nitrate, ammonium sulfate, ammonium nitrate, synthetic nitrogenous fertilizers, organic nitrogenous fertilizers, mineral phosphates, bone phosphate and basic slag, superphosphates, ammonia solutions, potash; sulfur, calcium, and magnesium; and trace elements. Following these are chapters on adjusting soil reaction and fertilizer practice to crop requirements, principles of purchasing and use of fertilizers. A chapter on liquid fertilizers is a new addition. Farmers would find the chapter on application of dry fertilizers especially helpful; considerable discussion is given to the effects of fertilizer placement. Completing the book are the recommendations for some field and horticultural crops published by the Joint Committee on Fertilizer Application. Close to 1,000 references to technical literature are included in the bibliography.

LABORATORY MANUAL FOR SOIL FERTILITY STUDENTS

By Darrell A. Russel and George Stanford. Wm. C. Brown Co., Dubuque, Iowa. 1954.

This is a second edition of the manual which first appeared under Prof. Russel's authorship in 1950. It is prepared for beginning students in soil chemistry and fertility and is designed for students who expect to specialize in agronomy or who want a specialized knowledge of soils applicable to other fields of agriculture. The new edition follows essentially the same organization as the original. Not included in this edition is the exercise on determination of exchangeable calcium, as well as the section on soil tests for farmer supplies and an explanation of soil test rec-

ommendations. The revision retains the two identical pages for recording the data from each exercise. With this convenient device the student may have a permanent record of all the exercises.

THE MICROPHYSICAL WORLD

By William Wilson. New York. The Philosophical Library. 216 pp. 1954. $3.75.

In an age popularly described by some as the "atomic age", it would seem imperative for every intelligent citizen to understand something about atomic structure. This little volume—3½ by 5½ inches—is a contribution to that understanding. The book itself, like a single atom, is small only in size. The discussion begins with the atomic theory of John Dalton, and traces the development of the succeeding ideas of atoms and molecules up to the quantum theory of Planck, and on to the current knowledge of heat, light, electromagnetism, radio-activity, cosmic radiation and other topics.

The author succeeds in conveying—to this reviewer, at least—some of the excitement which must have developed slowly in the community of scientists as knowledge of the microphysical world grew from hypotheses to statements of objective reality. Although written with a minimum of technical language for a layman reader, it is definitely not "popular" science reading. Dr. Wilson tells the reader in effect, "You ain't seen nothin' yet." Much is yet to be learned of the atoms and the sub-atomic world and "our beautiful quantum mechanics," he says, is not final. This note of expectancy should appeal to layman readers, and induce many of them to pick up the book again for a firmer grasp of the laws of the microphysical world.

GENETIC HOMEOSTASIS

By I. Michael Lerner. John Wiley & Sons, Inc. New York. 134 pp. 1954. $3.25.

The author defines genetic homeostasis as the property of a population to equilibrate its genetic composition and to resist sudden changes. He carefully develops and reviews evidence for the thesis that in cross-fertilizing organisms the process of development leads to uniform phenotypic expression in individuals of a given population in spite of genetic variability between them. Such populations tend to retain a genetic composition which produces a maximum average fitness in its particular environment.

He suggests that the most likely mechanism lies in a greater ability of the heterozygote to stay within the limits of normal development and in natural selection favoring intermediate rather than extreme phenotypes. The book is divided into three well written parts—I Definition and Hypothesis, II Evidence, and III Interpretation.

In relating the concepts developed in this readable book to practical animal improvement programs the author points out that, with the exception of single genes controlling morphological traits, the view that considers the main aim of breeders to be the fixation of desirable alleles is untenable since the basic requirement of a successful cross breeding population is the maintenance of heterozygosity. He suggests that further research in breeding be directed to more precise studies of population properties, of the forces of genetic homeostasis, and of the methods for overcoming them.

Although the book is directed mainly toward animal geneticists, the ideas presented provide material for serious thought to all geneticists interested in the evolution and improvement of plants and animals.—H. H. KRAMER.

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Bulletin of the Chinese Association for the Advancement of Science, Vol. I, No. 5, Taipei, Taiwan, China. Representative titles: Genetical expression of the OMM-type Hybrid obtained from the POJ2725 × *Miscanthus japonicus* cross; Phytogeographical affinities of southern Taiwan; Systematic study of Japanese protofloridae; Study of resistance to soil salinity of sugarcane varieties.

Guide to Cockle Park, Bulletin No. 56, King's College (University of Durham) Agricultural Experiment Station. A printed guide containing field index, description of land, livestock, fields, trials and nursery; departmental experimental reports and weather statistics.

Agronomic Affairs

MEETINGS

April 26, California Fertilizer Conference, Davis.
April 27–29, Arid Lands Symposium (AAAS) Albuquerque, N. Mex.
April 28–30, International Land Judging Contest, Oklahoma City, Okla.
June 15–17, Annual convention, American Seed Trade Assn., Minneapolis, Minn.
June 25–27, American Society of Commercial Seed Technologists, Stillwater, Okla.
June 27–29, North Central Branch, A.S.A., Iowa State College, Ames.
June 27–30, Association of Official Seed Analysts, Stillwater, Okla.
June 28–30, Pacific Northwest Regional Fertilizer Conference, Boise, Idaho.
July 27–29, Northeast Branch, American Society of Agronomy, Pennsylvania State University.
Aug. 1–6, 3rd International Congress of Biochemistry, Brussells, Belgium.
Aug. 15–19, American Society of Agronomy and Soil Science Society of America, University of California College of Agriculture, Davis.
Aug. 29–Sept. 6, International Horticultural Congress, Scheveningen, Holland.

FRED HULL ELECTED SOUTHERN BRANCH PRESIDENT

FRED H. HULL, Florida Agricultural Experiment Station, Gainesville, became new president of the Southern Branch of the American Society of Agronomy at the group's annual meeting, Louisville, Ky., February 8–9. He had served as vice-president of the branch during the past year and also as chairman of the branch's crop section.

Retiring president of the branch is ERIC WINTERS, University of Tennessee, Knoxville. New vice-president of the group is J. FIELDING REED, American Potash Institute, Atlanta, Ga. Reed has served as chairman of the soils section of the branch for the past year and will also continue in that capacity during the coming year.

JOHN GRAY, Louisiana State University, Baton Rouge, was elected to a 2-year term as chairman of the crop section. He had served during the past year as secretary. The new secretary is W. E. COLWELL, North Carolina State College, Raleigh.

A total of 167 persons attended the 1955 branch meeting. Next year's session will be held at Atlanta, Ga.

NEW POLICY COMMITTEE FOR SCIENTIFIC AGRICULTURAL SOCIETIES ORGANIZED AT JANUARY MEETING IN WASHINGTON

A new organization to represent agricultural professional and scientific societies at national level was officially launched Jan. 31, at Washington, D. C. W. H. GARMAN, well-known agronomist and administrator, was elected executive secretary of the body.

Five societies represented at the organizing session are, the American Dairy Science Association, American Society of Agricultural Engineers, American Society of Agronomy, American Society of Animal Production, and American Society of Range Management. The Soil Conservation Society of America helped to form the new Policy Committee but was not represented at the meeting.

The policy committee expressed hope that other professional societies in agriculture will participate in and lend support to its activities. No financial contributions or "dues" are required.

Main effort of the policy committee to date has been representation of agricultural societies before the Scientific Manpower Commission. The Committee is now recognized as the "voice" of agricultural scientific societies. It is expected that the committee will speak for agriculture with other national bodies, such as the National Research Council, in the future.

The committee also plans to explore plans whereby agricultural societies can reduce costs by working more closely together. Chief concerns have been the high costs of publishing journals and of maintaining headquarters for the various societies.

MONOGRAPH POLICY COMMITTEE NAMED

G. G. POHLMAN of West Virginia University, president of the American Society of Agronomy, has named a 3-man committee to study the future policy of the Society's Monograph Series. Members of the committee are I. J. JOHNSON, Iowa State College, vice president of the Society; R. J. MUCKENHIRN, University of Wisconsin, and L. G. MONTHEY, executive secretary of the Society.

INTERNATIONAL HORTICULTURAL CONGRESS

The 14th International Horticultural Congress will be held Aug. 29–Sept. 6 at Scheveningen, Holland. E. C. STAKMAN, emeritus professor at the University of Minnesota, will deliver one of the three general lectures. His topic is "The Application of Atomic Energy in Horticulture." Eleven symposia are planned. H. E. HAYWARD of the U. S. Salinity Laboratory, Riverside, Calif., will lead the symposium on salt toleration and drought resistance. Included among the numerous tours are two soil excursions. Secretary of the Congress is G. DE BAKKER, 30 Bezuidenhoutsweg, The Hague, Holland.

MANY PARTICIPATE IN ARID LANDS SYMPOSIUM

D. W. THORNE of Utah State Agricultural College, vice president of the Soil Science Society of America, will be the official representative of the Society and the American Society of Agronomy at the International Arid Lands symposium April 27–29 at Albuquerque, N. Mex.

The symposium is sponsored by the American Association for the Advancement of Science, and is supported by the National Science Foundation, the Rockefeller Foundation and the UN Educational, Scientific, and Cultural Organization.

Technical sessions will be held to consider the following topics: variability and predictability of water supply in arid regions, better use of present resources, prospects for additional water sources, and better adaptation of plants and animals to arid conditions. In addition to these sessions, special conferences, field trips, and lectures are planned.

Among the Society members who have been invited to present formal papers are L. A. RICHARDS, U. S. Salinity Laboratory, Riverside, Calif.; CHARLES E. KELLOGG, SCS, Washington, D. C.; H. E. HAYWARD, Salinity Laboratory, Riverside, Calif.; O. S. AAMODT, USDA, Beltsville, Md.; R. MERTON LOVE, University of California, Davis; T. F. BUEHRER, University of Arizona, and M. R. HUBERTY, University of California, Los Angeles.

COMPLETE SET OF PROCEEDINGS AND JOURNAL AVAILABLE

A complete set, Vols. 1 through 18, of the *Soil Science Society of America Proceedings*, and a complete set, Vols. 1 through 46, of the *Agronomy Journal* are both available for purchase. Any interested person, agency or library may contact the Executive Secretary, American Society of Agronomy, 2702 Monroe St., Madison 4, Wis., for further information.

MORRIS HEADS GEORGIA SECTION OF SOCIETY

HAROLD D. MORRIS of the University of Georgia College of Agriculture, was elected chairman of the Georgia Section, American Society of Agronomy, at the section's meeting Jan. 17–19 at Athens. He succeeds J. M. ELROD. JULIAN MILLER was elected vice chairman, succeeding JOEL GIDDENS. HAYDEN ROGERS is permanent treasurer.

The following participated in the program and discussion: A. A. NIKITIN; J. A. HUNTER; H. D. MORRIS; D. D. MOREY; A. R. BROWN; J. G. FUTRAL; R. H. TROUPE; JOEL GIDDINS; H. F. PERKINS; H. B. HARRIS; E. S. LUTTRELL; J. W. DOBSON, JR.; S. B. PARKMAN; L. F. BAUMAN; A. A. FLEMING; G. M. KOZELNICKY; G. A. LEBEDEFF; J. L. BUTLER; J. H. MACHMER; W. H. FREEMAN; E. C. WESTBROOK; E. H. DEVANE; G. M. PRINE; IAN FORBES and H. A. INGLIS.

QUIZ MEMBERS ON TOURS AT ANNUAL MEETING

To help local arrangements committees with plans for the Society annual meeting Aug. 15–19 at Davis, Calif., all members of the Society have received questionnaires listing several proposed field trips to be held in conjunction with the meeting.

Members interested in the trips are requested to indicate their preference as to the tours themselves as well as to the time of the tours. Proposed tours are as follows:

All-day tour of San Francisco and vicinity; all day tour to Sacramento and vicinity (both primarily for women and children).
All-day soil field trip in the Sacramento Valley.
Agronomy field trip, Sacramento Valley.
Wildland field trip in mountainous areas.
All-day trip to Hopland Field Station.
All-day soil conservation field trip.
All-day alkali soils field trip in San Joaquin Valley.
Conducted tour of University of California campus at Berkeley.

Four tours to inspect certified alfalfa seed production in various sections of the state also have been proposed by the Certified Alfalfa Seed Council.

Persons taking any of the tours will pay their own transportation.

CALIFORNIA AND WESTERN WEED CONFERENCES WILL MEET IN SACRAMENTO IN 1956

The eighth annual meeting of the California Weed Conference and the fifteenth Western Weed Control Conference will be held jointly in Sacramento, Calif., on Feb. 15–17, 1956.

The seventh annual meeting of the California Weed Conference was held on Jan. 26–27, in Santa Barbara, Calif. During the 2-day session, state, federal, and local weed control officials, together with industrial personnel and interested farmers and ranchers were presented with the latest information on California's manifold weed control problems. Among problems discussed were the costs of weeds, poisonous plants, brush, cattail and tule, cotton weeds, and industrial weed control; poisonous plants, 2,4-D hazards and herbicide formulation problems, CMU in citrus orchards, and new chemicals.

Officers of the eighth California Weed Conference are PAUL DRESHER, American Chemical Paint Co., San Jose, Calif., president; JAMES KOEHLER, California Department of Agriculture, Los Angeles, vice president; O. A. LEONARD, University of California, Davis, secretary; VERNON HALL, Chipman Chemical Co., Palo Alto, treasurer.

Officers of the Western Weed Control Conference are: WALTER BALL, California State Department of Agriculture, Sacramento, president; W. A. HARVEY, University of California, Davis, vice president; W. C. ROBOCKER, USDA, Reno, Nev., secretary-treasurer.

PENNINGTON HEADS POTASH INSTITUTE CANADA OFFICE

ROY PENNINGTON, with the agronomy department of Pennsylvania State University since 1949, was appointed manager of the American Potash Institute's Canadian office effective Feb. 1. He succeeds E. K. HAMPSON, who retired after serving as Canadian manager since the Institute was formed in 1935.

Dr. Pennington is a native of Toronto. He attended Ontario Agricultural College, receiving the B.S.A. degree in 1942. He began his work in soil fertility and plant nutrition at Pennsylvania State University in 1949 after receiving the Ph.D. degree from the University of Wisconsin.

Mr. Hampson's career in agriculture started with his graduation from the University of Toronto in 1915. He was then an agricultural representative with the Ontario Department of Agriculture for 4 years, and then professor of field husbandry and soil at the Kemptville Agricultural School for 9 years. From 1928–1935 he was Ontario representative for N. V. Potash Export Co.

HEAD OF BRITISH SOIL SOCIETY VISITS U. S.

A. M. SMITH, president of the British Society of Soil Science, will visit the United States during April and May. Dr. Smith is head of the chemistry department at the Edinburgh and East of Scotland College of Agriculture, and lecturer in agricultural and forest chemistry at the University of Edinburgh.

NEWS ITEMS

GEORGE R. BLAKE has been research associate in soil physics since Feb. 1 in the soils department, University of Minnesota. He had been assistant professor of soils at Rutgers University for 6 years before moving to St. Paul. He received his Ph.D. degree at Ohio State University in 1949.

—A—

H. H. RAMEY, JR., joined the staff of the Delta Branch Experiment Station, Stoneville, Miss., on Feb. 7. His work there is in cotton breeding and genetics.

—A—

HENRY H. FRIBOURG, who received the Ph.D. degree in July 1954 from Iowa State College, has been stationed at Camp Detrick, Md., since his induction into the U. S. Army last September. He is doing research work in the Chemical Corps Biological Laboratory. Prior to his induction, he participated as chief interpreter in the Caribbean Agricultural Extension Conference at Kingston, Jamaica.

—A—

I. BERGSTEINSSON has been appointed senior market research and development engineer for Brea Chemicals, Inc.

—A—

JOE L. KIRK has been appointed director of sales and advertising for the Douglas Chemical Co., manufacturers of fumigants, insecticides and agricultural chemicals.

—A—

CARL THOMAS BLAKE has been appointed agronomy specialist with the North Carolina State College Extension Service. He is a graduate of State College and had previously served as assistant county agent in Currituck.

—A—

JOHN HOLLABOUGH, JR., has been appointed research assistant at the Rice Branch Experiment Station, Stuttgart, Ark., and MAX TAYLOR has been appointed to a similar post at the Alfalfa Substation of the Arkansas Experiment Station.

J. HAMILTON SMITH has accepted a joint appointment at Clemson, S. C., between the South Carolina Agricultural Experiment Station and the Eastern Soil and Water Management Section of the Agricultural Research Service, USDA. Mr. Smith recently completed work on his doctorate in soil microbiology at Cornell University. His new work will deal largely with microbiological aspects of mulch tillage in the Southeast.

—A—

WILLIAM L. GARMAN has assumed duties as agricultural service manager for the Grand River Chemical Division of Deere and Co. at Tulsa, Okla. From 1950 until this appointment, he was with the agronomy department of Cornell University. He is a graduate of Oklahoma A and M College where he also received his M.S. degree, and earned his Ph.D. degree at Ohio State University.

—A—

G. T. WEBSTER, head of the agronomy department, University of Kentucky, announces the following staff additions:

WILLIAM H. STROUBE, formerly of Louisiana State University, is now in charge of grass and legume evaluation studies. TIMOTHY H. TAYLOR is working in pasture research, having come recently from the Northern Virginia Pasture Research Station, Middleburg, Va. He recently received his Ph.D. degree from Pennsylvania State University. H. RANDOLPH RICHARDS has joined the staff as assistant agronomist at the Princeton Substation. GEORGE EVERETTE, previously employed as a county agent in Kentucky, has joined the agronomy staff as tobacco extension specialist.

COMMERCIAL NEWS

A new agricultural tank sprayer, the Agi-Sprayer, capable of mixing and applying all soluble and liquid materials, as well as many non-soluble suspension materials, hitherto believed unsuited for spraying, is announced by Nutritional Concentrates, Inc., New Lexington, Ohio. According to the manufacturer, it permits control of pH, as well as of the availability of major elements and trace minerals.

—A—

A new covering device, named the Furrow-Master, designed to fit any moldboard plow is announced by the Russell Mfg. Co., Caro, Mich. Its function is to hold down the trash and push it into the furrow ahead of the soil. It is adjustable to suit individual soil and trash conditions, and is designed to fit the different curves of various moldboards.

—A—

The 1955 issue of "Everything in Safety," a catalogue of personal protective equipment and industrial safety devices is now available at no cost from the General Scientific Equipment Co., 2700 W. Huntington St., Philadelphia 32, Pa.

—A—

A new Model 146 Flame Photometer, is announced by the Perkin-Elmer Corp., Norwalk, Conn. It uses a duo-prism monochromator to provide maximum discrimination between elements and the most rapid selection of the wavelengths of all elements that emit in a gas flame. Analyses may be made in solution on sodium, lithium, potassium, magnesium, calcium, strontium, barium, chromium, and manganese.

PERSONNEL SERVICE

The Personnel Service column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of $2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a key number which will be carried for five additional insertions unless a discontinue order is received. Items pertaining to soils positions will be inserted one time in the *Soil Science Society of America Proceedings* unless otherwise specified. The following insertions, published in earlier issues, are still available: 11–1, 11–2, 12–1, 1–1, 2–1, 2–2, 2–3.

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AGRONOMY JOURNAL

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Winter Hardiness of Birdsfoot Trefoil Strains and Varieties[1]

Kenneth O. Rachie and Alois R. Schmid[2]

THE use of birdsfoot trefoil (*Lotus corniculatus* L.) as a permanent pasture legume is dependent in part on its ability to survive winter injury. In Minnesota and other northern areas where birdsfoot trefoil might be grown, there appears to be some doubt as to the winter hardiness and persistence of this legume. For this reason, studies were made on the relative winter hardiness of birdsfoot trefoil strains and varieties.

Winterkilling may be the result of several factors. Levitt (7) has reviewed much of the work done on the physiology of winter hardiness. Among the factors for winterkilling most often listed and studied are varieties, food reserves, heaving, ice sheet injury, diseases and chemical makeup of the plant as influenced by soil fertility. Important studies of these factors, particularly as related to legumes, have been reported by many workers (1, 2, 3, 4, 5, 6, 10, 11, 14, 15, 16, 17, 18). The stage of development of plants and their resistance to cold injury was studied by Tysdal and Pieters (16) and Peltier and Tysdal (12). Several workers have observed differentials in winter killing among varieties and strains within a species. Aamodt, *et al.* (1) noted differences among strains of white clover. Brink, *et al.* (2) studied alfalfa strains and found significant differences among them. Since disease is an important factor, it is of interest to note that MacDonald (9) reports that clover root rot, *Sclerotinia trifoliorum*, has been observed to infect birdsfoot trefoil and cause a reduction of stand. Lewis and Sherwin (8) observed that *Rhizoctonia solani* also attacks birdsfoot trefoil.

The investigations presented here include artificial hardening and freezing of different varieties grown in the greenhouse, and observations made on winter killing of varieties grown in the field. These artificial treatments were used to compare tissue hardiness of different varieties and to supplement studies made in the field since winter killing varies considerably from year to year.

MATERIALS AND METHODS

Greenhouse Experiment

Plants were grown in the greenhouse to different stages of development, artificially hardened, and frozen in a walk-in type freezer. Ranger alfalfa and Ladino clover were used for comparison with birdsfoot trefoil in this experiment. Ranger alfalfa is sufficiently winter-hardy in Minnesota to survive most winter conditions encountered. Ladino clover, on the other hand, is more susceptible to winterkilling.

Five different freezings were made on Ranger alfalfa, Ladino clover, and five varieties of birdsfoot trefoil namely, Viking, Empire, Cascade, Granger, and Italian. Seedlings were made in 6-inch clay pots, and enough seed was used to give at least 30 seedlings per pot for the earlier treatments and at least 20 seedlings per pot for the later treatments.

A greenhouse potting soil consisting of an equal mixture of soil, sand, and manure was used. All the pots and soil were steam sterilized before planting. The seed was treated by dusting with Spergon. The seeds were carefully scattered in the pot and kept at least 1/2 inch away from the sides of the pot to avoid unequal freezing injury near the outside. The seed was covered with 1/8 inch of lightly packed soil. A generous sprinkling of the appropriate Rhizobia was then made on top of the soil to be washed down to the seedlings with later waterings. The pots were regularly watered to insure optimum growth. The greenhouse temperature was kept at about 22° C. except on sunny days when the temperature was higher. Artificial light was not used since the experiments were started late in March when natural light was ample.

After 2 weeks of growth, the seedlings in each pot were thinned to approximately 20 to 30 plants per pot. Hardening of the plants and freezings as described later were made after 14, 19, 24, 36, and 44 days of growth. Each variety was duplicated in each treatment and the pots were randomly arranged in two blocks. Seedings for all treatments were made on the same day and the hardening and freezing treatments were made after the prescribed number of days of growth in the greenhouse.

When the prescribed number of days of growth for each treatment had elapsed, the seedlings were transferred to the hardening chamber for 14 days. In the hardening chamber the temperature was maintained at 3° C. Fluorescent lights about 18 inches above the seedlings were continuously used. Water was supplied when needed. Very little or no growth was observed in the hardening chamber.

After hardening, the pots were transferred to the freezing chamber for 12 hours at −10° C. Before freezing, notes were taken on height of plant, number of trifoliolate leaves and the number of plants per pot. After freezing, the pots were returned to their original position in the greenhouse and the number of surviving plants was recorded 10 days later.

Field Experiments

Two separate studies were made of the survival of birdsfoot trefoil varieties in the field. One study was conducted at Rosemount where five varieties of trefoil and Ranger alfalfa were seeded on June 20, 1951. Each plot consisted of 10 rows, 6 inches apart, and replicated 6 times. Four-hundred pounds per acre of 0–20–10 fertilizer were applied before seeding. The birdsfoot trefoil varieties and Ranger alfalfa were seeded with a 1-row garden planter at a rate of 5 and 12 pounds per acre, respectively.

On May 6, 1952, the percent survival of each variety was calculated from the plants remaining alive. Plants 5 feet in from each of 2 center rows of each plot were counted.

The second study of variety survival was carried on at the University Farm in St. Paul. In this experiment six varieties of birdsfoot trefoil plus Ranger alfalfa were included. These varieties were Oregon Narrowleaf, French Broadleaf, Italian Broadleaf Granger, Empire, and Cascade. These plots were seeded on July 22, 1952 and consisted of 12 rows, 6 inches apart and 20 feet long. Plots were again replicated 6 times and the seeding was also done with the garden seeder calibrated for 10 pounds per acre of alfalfa and 5 pounds per acre of trefoil. All seeds were inoculated with their appropriate nitrogen-fixing bacteria. The percent survival of the varieties was calculated from counts made on the same area on Sept. 19, 1952 and again on April 23, 1953. Counts were made on 12 feet of a row. Notes were also taken on height of plants and their over-all vigor. In the spring of 1954 a note on percent survival was obtained by eye estimation.

[1] Contribution from the Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, Minn. Paper No. 3210, Scientific Journal Series, Minnesota Agr. Exp. Sta. Part of a thesis submitted to the Graduate School by the senior author in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Rec. for publication Aug. 26, 1954.

[2] Former graduate student and Associate Professor of Agronomy, respectively.

Table 1.—Survival after artificial freezing of Ranger alfalfa, ladino clover and birdsfoot trefoil varieties after 14 to 44 days of growth in the greenhouse.

Variety	14 days		19 days		24 days		36 days		44 days		Average percent survival
	Stage	Percent survival	Stage	Percent survival	Stage	Percent survival	Stage	Percent survival	Stage	Percent survival	
Ranger alfalfa	2–3 in. 1-leaf	0.0	2–3 in. 3-leaf	91.3	5–6 in. 5-leaf	100.0	8–9 in. 9-leaf	100.0	9–11 in. 12-leaf	100.0	97.8
Ladino clover	2–3 in. 1-leaf	0.0	2–3 in. 1-leaf	47.2	3 in. 2-leaf	79.3	3–4 in. 4-leaf	50.7	7–8 in. 5-leaf	16.0	48.3
Viking trefoil	2–3 in. 3-leaf	0.0	3–4 in. 5-leaf	88.1	4–5 in. 6-leaf	88.6	6–7 in. 9-leaf	72.1	8–9 in. 10-leaf	95.0	86.0
Empire trefoil	2–3 in. 2-leaf	0.0	2–3 in. 4-leaf	81.6	4–6 in. 6-leaf	83.9	7–9 in. 8-leaf	85.0	9–10 in. 11-leaf	100.0	87.6
Cascade trefoil	2–3 in. 3-leaf	0.0	3–4 in. 5-leaf	56.9	4–5 in. 7-leaf	79.1	6–7 in. 9-leaf	91.2	7–8 in. 11-leaf	97.6	81.2
Granger trefoil	2–3 in. 3-leaf	0.0	3 in. 5-leaf	50.0	5–6 in. 7-leaf	71.8	6–7 in. 10-leaf	70.6	8–9 in. 12-leaf	68.3	63.9
Italian trefoil	2–3 in. 3-leaf	0.0	3–4 in. 5-leaf	35.4	5–6 in. 7-leaf	56.3	6–7 in. 9-leaf	55.5	7–8 in. 10-leaf	82.3	57.4
Average		0.0		64.4		79.9		75.0		79.9	74.8
L.S.D. between varieties at 5%											21.4

EXPERIMENTAL RESULTS

Greenhouse Experiment

Data obtained from the artificial freezing study are shown in table 1. When the plants were allowed to grow only 14 days in the greenhouse before hardening and freezing, no plants survived. Therefore, results from this stage were omitted from the analysis of variance. According to the analysis, the F values for varieties and for varieties × treatments were significant at the 1% level.

Ranger alfalfa had significantly greater hardiness than Ladino clover, Granger and Italian trefoil. In this experiment Ranger alfalfa did not have a significantly higher survival rate than Viking, Empire, and Cascade trefoils. Nevertheless, it was consistently superior for each growth period (19, 24, 36 and 44 days of growth before hardening and freezing) and had more recovery vigor, suggesting that it is superior to these three varieties in hardiness.

Viking, Empire and Cascade birdsfoot trefoils are more resistant to freezing injury than Italian birdsfoot trefoil and Ladino clover. Viking and Empire may be hardier than Granger. No other varietal differences are significant. Ranger alfalfa, Viking and Empire trefoils, under the conditions of this experiment, seemed to approach maximum survival rate with 19 days of growth before hardening and freezing. Ladino clover and Cascade, Granger and Italian trefoils, appeared to continue to increase in hardiness up to 24 days of growth. The survival of Ladino clover decreased sharply from the 24-day growth period to the 44-day growth period and was less hardy at the 44-day growth period than at the 19-day growth period.

Field Experiment At Rosemount

Five varieties of birdsfoot trefoil and Ranger alfalfa were seeded on June 20, 1951 at Rosemount. Observations made the following spring on survival of these varieties are recorded in table 2.

The most striking result is that four varieties of birdsfoot trefoil, Granger, Italian, French, and Oregon Narrowleaf were completely winterkilled and that Ranger alfalfa and Empire birdsfoot trefoil survived relatively well.

Ranger alfalfa was found to have significantly more winter hardiness than Empire trefoil in this comparison.

Field Experiment at University Farm, St. Paul

Another variety seeding was made at the University Farm in St. Paul on July 22, 1952 to test further the relative hardiness of birdsfoot trefoil varieties. Seven varieties of trefoil and Ranger alfalfa were used in this trial. The data on percent survival after each of the two following winters are presented in table 3.

In the 1952–53 winter, Ranger alfalfa and Empire trefoil had significantly better survival than Oregon Narrowleaf, Italian and French. Ranger and Empire, although not significantly different from Cascade and Granger, tend to be consistently higher in survival. During the 1953–54 winter the varieties French, Italian, Oregon Narrowleaf, Granger and Cascade were almost eliminated by winter injury. Only Ranger alfalfa and Empire birdsfoot trefoil showed good survival.

Table 2.—Survival of birdsfoot trefoil varieties and Ranger alfalfa in field trials at Rosemount, Minn., after the winter of 1951–1952.

Variety	Percent survival
Granger	0
Italian	0
French	0
Oregon Narrowleaf	0
Empire	86.0
Ranger alfalfa	97.8**

** Difference between Empire and Ranger alfalfa significant at 1% level.

Table 3.—Survival of birdsfoot trefoil varieties and Ranger alfalfa after the winters of 1952–1953 and 1953–1954.

Varieties	Percent survival	
	1952–1953	1953–1954
French	87.6	4.0
Italian	55.6	4.0
Oregon Narrowleaf	74.1	2.0
Granger	92.1	3.0
Empire	99.1	89.0
Cascade	93.2	2.0
Ranger alfalfa	99.3	93.0

L.S.D. between varieties at 5% = 7.3 for the 1953 winter.

DISCUSSION

Ranger alfalfa generally had more winter hardiness than any of the trefoil varieties tested in all studies made. However, in some cases in both the field and greenhouse, no significant differences could be found between Ranger alfalfa and Empire, Viking, Cascade, or Granger birdsfoot trefoil. The reason might have been due to a freezing temperature that was not low enough to get a good differential in the greenhouse experiments. At University Farm in St. Paul, the winter of 1952–53 was not rigorous enough to severely injure even the least hardy varieties. During the 1953–54 winter the varieties French, Italian, Oregon Narrowleaf, Granger and Cascade were severely winter injured. At Rosemount the 1951–52 winter was severe, and the trefoil varieties—Granger, Italian, French, and Oregon Narrowleaf—were completely killed while Ranger alfalfa, and Empire birdsfoot trefoil showed good survival.

Empire birdsfoot trefoil in the field and greenhouse is somewhat more cold resistant than other varieties of trefoils tested. In the greenhouse, however, Viking was not observed to be significantly less hardy than Empire. Further study of the winter hardiness of Viking in the field and by artificial freezing seems warranted since this variety had good vigor, resistance to disease, and recovery from freezing. Seed of this variety was not available in time to be included in these field studies. Although Empire has good cold hardiness, it has a slower recovery and seems to have less vigor than other varieties of trefoil. This is in agreement with Ronningen's (13) work on white clover when he obtained a significant negative correlation between vigor and winter hardiness.

The results obtained with Ladino in the greenhouse were quite variable. This may have been due to Ladino having a rather narrow range of freezing resistance or because resistance to freezing fluctuates with growth.

Freezing at different stages of growth was studied to determine how soon seedlings obtain sufficient cold hardiness. The first artificial freezings were made when all seedlings had made a minimum of 14 days of growth, and all varieties were killed at this stage. Ranger alfalfa, Viking and Empire trefoil, had very good resistance to freezing after 19 days of growth, each averaging better than 80% survival. Ladino, Granger, Cascade, and Italian seem to require more than 19 days of growth before obtaining relatively good resistance to freezing. Peltier and Tysdal (12) concluded that 10 to 18-day old alfalfa seedlings are relatively susceptible to freezing in comparison to both younger and older seedlings. Tysdal and Pieters (16) also showed that alfalfa and red clover increase in cold resistance with advance in age after the two-leaf (trifoliolate leaves) stage. The results presented here agree with those of Peltier and Tysdal and Tysdal and Pieters. Certain varieties of trefoil however, probably require longer growth than others before they can tolerate freezing temperatures.

SUMMARY

Winter hardiness experiments using field conditions and artificial freezing showed that Empire birdsfoot trefoil was more winter-hardy than the other trefoil varieties tested, with the possible exception of Viking, which was tested only by artificial freezing.

There were no varieties which survived freezing after only 14 days of greenhouse growth, but all varieties had at least fair survival after 19 days of greenhouse growth. Ranger alfalfa, Empire, and Viking birdsfoot trefoil had good survival after 19 days of greenhouse growth, whereas Ladino clover, Granger, Cascade and Italian birdsfoot trefoil were less hardy at this stage of growth.

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Evaluation of Combining Ability in Orchardgrass *Dactylis glomerata* L.[1]

Donald L. Oldemeyer and A. A. Hanson[2]

RECOGNITION of the importance of grassland farming and the need for improved forage production has emphasized the demand for superior forage varieties. Selecting parents which transmit desirable characters to their progenies is the main problem that confronts the plant breeder in developing such varieties.

Combining ability has been recognized in selecting desirable inbred lines of corn. The success of this type of selection is well illustrated by the improved performance of hybrid corn varieties. On the other hand, neither the methods nor the importance of selecting on the basis of combining ability have been adequately investigated for perennial forage grasses.

This investigation was undertaken to compare three different means of evaluating combining ability in orchardgrass. The methods differed by the range of pollen available to the parents for fertilization. The pollen sources were varied by including selected clones in wide and restricted polycross nurseries and in single-cross blocks.

REVIEW OF LITERATURE

Tysdal and Crandall (7) demonstrated the need for selecting parents of high combining ability to produce high yielding alfalfa synthetics. They produced two synthetics, one with high combining parents and one with low combining parents. The former yielded 29% more forage in the first generation than did the low combining synthetic. They concluded that as long as there is considerable genetic variability among the lines in the polycross nursery, the polycross test should measure general combining ability efficiently. Eight alfalfa clones evaluated through progenies from single-crosses, a polycross nursery, a polycross nursery with Arizona Common in alternate rows, and top-crosses with Arizona Common, ranked practically the same in each test.

Knowles (4) studied combining ability in smooth bromegrass and crested wheatgrass. Combining ability ratings from open-pollinated progenies agreed with the ratings from controlled crosses among clones of crested wheatgrass. A reasonably good agreement was noted between the yields of variety top-cross and open-pollinated progenies. The polycross and open-pollinated progenies of bromegrass gave similar yields; however, a non-significant correlation was obtained between the yields of open-pollinated and single-cross progenies. The lack of agreement was attributed to the presence of selfing in the single-crosses. In general, Knowles found a poor relationship between parental performance and progeny performance. He suggested the use of open-pollinated progenies to evaluate selections for yield potential. He agreed with Sprague and Tatum (6) that general combining ability is more important than specific ability in lines not previously tested and selected for combining ability.

Weiss, *et al.* (9) found very little association between orchardgrass clones and their open-pollinated progenies for forage yield or leafiness. Poor association was also noted between the yields of single-crosses and the mean yields of the parents. The test was planted in 3-foot drill rows. They stated that the use of broadcast plots probably would have given a more accurate evaluation of progenies. They mention that the open-pollinated seed was obtained from single plants in a space-planted nursery. Thus, male parentage was confounded in their experiment.

Murphy (5) compared the performance of parental clones with that of polycross and selfed progenies from three species of grasses. Drilled, broadcast, and spaced plantings were used. Significant positive correlations were obtained between parental and progeny yields regardless of method of planting. According to these investigations, any of the methods tested could be used in selecting for high yield potential.

Hanson, *et al.* (2) compared the general combining ability of 18 parental clones of orchardgrass and 52 of their inbred lines in broadcast plots. The results indicated that there was little relationship between combining ability and level of inbreeding. They suggest that lines within families should be evaluated for combining ability.

Wilsie and Skory (10) found a possible association between forage yields of single-cross and open-pollinated progenies of alfalfa clones that might be of assistance in evaluating combining ability. They stressed the need of determining specific combining ability in the selection of lines to be included in synthetics.

Bolton (1) and Knowles (4) compared reciprocal crosses and found very little difference in their behavior. Knowles did find some instances in bromegrass where significant differences occurred. Self-fertilization during crossing was suspected to have caused the differences.

Hawk and Wilsie (3) found greater variation in forage yield of parental clones than for open-pollinated progenies in bromegrass. Of 78 clones evaluated, only a few produced open-pollinated progenies superior in yield. Yielding ability of the parents and the open-pollinated progenies showed some relationship. They attributed 20 to 35% of the variability in progeny yields to differences in the yield potential of the parents. They advocate careful screening of parental material before progeny testing and the use of replicated single hill nurseries for clonal evaluation. They obtained data that would indicate seedling vigor tests may be of value for screening large numbers of open-pollinated progenies.

In testing six ways of planting, Weiss and Mukerji (8) found that broadcasting orchardgrass alone gave more accurate evaluation of strains than 1-foot or 3-foot drill rows. Broadcasting with alfalfa and birdsfoot trefoil were used as standards of the true potential of the lines.

MATERIALS

The parental clones trace back to a source nursery of 4,000 spaced plants. Of the original plants, 257 were selected and planted in a polycross nursery. Seed from 102 of these was planted and 38 selections were made on the basis of observational notes taken in the progeny test and in the clonal nursery. These were grouped according to maturity and planted into seven restricted polycross nurseries. The parents included in two of these nurseries were used in this study. Seven of the clones used were in an early group with May 31 as the average date of heading. June 11 was the average for the five clones in the late maturing group.

All of the seed used in the field experiments was harvested in 1949. Seed from the parental clones was collected at all locations in a wide polycross nursery having a total of 112 clones in 6 replications of 5 plants each. Progenies from this source will be referred to throughout the report by the abbreviation WPC.

Seed was harvested from each parent in their respective restricted polycross nurseries. The parents were planted in 10-plant rows and replicated 15 times in these nurseries. Progenies from this source will be designated by the abbreviation RPC. In addition to the bulked seed of individual parents, an early and a late synthetic were made by compositing equal quantities of RPC seed from parental clones of each group.

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Single-cross seed was obtained by interplanting the parents in all possible combinations within the early and late groups. Isolation was attained by dispersing the crossing blocks in wheat fields. The blocks consisted of 2 alternate 20-plant rows of each parent. Seed from each parent was harvested and threshed separately. To supplement this seed, panicles from adjacent plants were bagged in the restricted polycross nurseries. Since the supply of single-cross seed was insufficient for planting reciprocal crosses, each parent was represented by an equal weight of seed in the single-cross lots.

EXPERIMENTAL PROCEDURE

To obtain fertility indexes for the parents, panicles were bagged in 1950 and 1951. A total of 60 panicles per parent was used to determine the seed set under bags and an additional 60 panicles were used to determine open-pollinated seed set. Two parchment bags enclosing 3 panicles were placed on 10 plants of each parent for selfing and likewise for containing the open-pollinated panicles after fertilization. Self-fertility is expressed as a percentage of open-pollinated seed set.

The progenies were tested in two field experiments corresponding to the two maturity groups. The 7 early maturing parents and their progenies were planted in a randomized block design with 4 replications of 4- by 16-foot plots. Progenies of the five late maturing clones were planted as a split plot design of four replications with each entry being represented by a broadcast and a space-planted plot. The spaced individuals were established in 12-plant plots with a spacing of 2 feet within rows and 3 feet between rows.

The parents were included in both experiments as tiller plots. Tillers were established in flats after being rooted in water and transplanted on 6-inch centers in the field to simulate broadcast plots. The plot size, 4 by 8 feet, was only half that of the seeded plots.

Forage yields were obtained in 1951 and 1952. Both years were droughty so only two harvests were taken each year. First harvests were cut at full bloom and the second were cut when the grass was 6 to 8 inches tall. The spaced plants were harvested individually in 1951 and by plots in 1952. Yields are reported as oven-dry hay containing approximately 5% moisture.

In addition to the field experiments, 2 seedling trials were conducted in the greenhouse in the fall of 1951 to correspond to the 2 field experiments. They were designed to compare seedling vigor with field performance. The early maturing group was planted in a 6 by 7 triple rectangular lattice and the late group was arranged in a 5 by 5 triple lattice, both with 6 replications. The plots were arranged so that each flat contained one block with a border. A plot consisted of 2 rows of 6 plants. The eight inside plants of each plot were harvested.

The seedlings were harvested 53 days after planting. Plants from each plot were bulked, after cutting the tops from the roots, for drying. Root and top weights were recorded separately.

Correlation coefficients calculated for the agronomic characters were obtained by combining the data of the early group and the late group planted in broadcast plots. This gave 10 degrees of freedom for the r values to show parent-progeny relationships. The data from the two experiments were adjusted to their respective means in computing the sums of squares and sums of products.

EXPERIMENTAL RESULTS

FERTILITY INDEXES

According to the fertility indexes (table 1), all parents were highly self-sterile with the exception of parents MI-13 and MII-34 in the early maturity group and MIV-6 in the late group. The average fertility indexes for these 3 clones were 80, 22, and 35, respectively. No significant relationship was noted between selfed-seed set and open-pollinated seed set, the correlation coefficient being 0.26.

FORAGE YIELDS

Average yields of the parents and progenies for 1951 and 1952 are shown in figures 1 and 2. The single-cross yields are the average of all crosses involving the respective parents.

Table 1.—Average seed set per panicle for 2 years and the fertility indexes of all parents given in percentage of selfed seed set to open-pollinated seed set.

Parents and Group	Seed set per panicle		Fertility Index
	Open-pollinated	Selfed	
Early Maturity			
MI-13	114.5	92.0	80
MI-14	69.5	2.5	4
MI-16	233.5	4.5	2
MI-17	155.0	1.5	1
MII-30	383.0	2.0	1
MII-34	94.5	20.5	22
MII-36	236.0	9.0	4
Late Maturity			
MIV-5	548.0	23.0	4
MIV-6	515.5	178.0	35
MIV-11	529.0	10.0	2
MIV-14	328.5	9.5	3
MIV-16	292.5	17.0	6

Significant differences in yields among entries were found in both experiments. The parents were predominately higher in yield than the progenies, mainly because the tiller plots became established faster and maintained this advantage possibly as a consequence of lower plant population. In both experiments, there was a significant interaction (0.01) of years × strains; however, significant correlations were found between the yields taken in 1951 and those in 1952. The interannual correlations for yields of parents, single-crosses, restricted polycrosses, and wide polycrosses were 0.58, 0.93, 0.87, and 0.94, respectively.

Considering the parent-progeny relationships, good associations were found as indicated by the correlation coefficients in table 2. All of the parent-progeny correlations were significant at the 0.05 level using the 2-year average yields. With the annual yields, some of the correlations only approached significance. The closest relationships existed between the parents and progenies of the late group planted in broadcast plots (figure 2).

Results of the space-planted portion of the late group experiment were somewhat different from those of the broadcast portion. There was a significant interaction of strains with methods of planting. MIV-14 appeared as one of the high yielding parents with high yielding polycross progenies contrary to the findings in the broadcast portion of the experiment.

Relationships among the progenies for yield were of about the same degree as between parents and progenies. In both instances, however, the correlation coefficients with the RPC's tended to be lower.

Mean yields of the single-crosses among the early parents are given in table 3. Specific combining ability was shown by all of the parents except MI-13 and MII-30. Each one had a single-cross that deviated significantly from the average of all the respective single-crosses. In all instances except MII-34 × MI-17, these crosses showed increases over the averages. Of the crosses with MI-13 and MII-30, all but one with each parent yielded above the average of all the single-crosses of the other parent in the crosses.

Single-crosses of the late maturing parents planted in broadcast plots (table 4) yielded as might be expected from the results of the polycross progeny tests and the parental

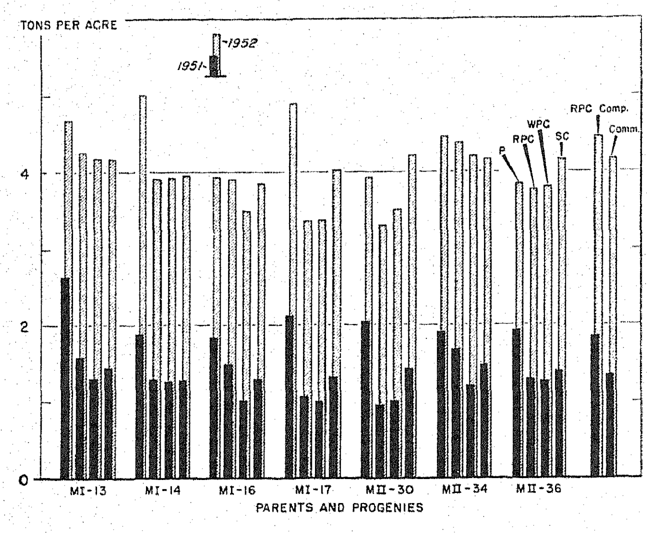

FIG. 1.—Average forage yields from the early maturity group for parents and progenies for two years. The single-cross yields are averages of all single-crosses for the respective parents.

Table 2.—Correlations among characters of parents and various types of progenies in broadcast† plots.

Character	Year	Single crosses	Re-stricted poly-crosses	Wide poly-crosses
Yield:				
Parents	1951	0.66*	0.52	0.63*
Parents	1952	0.54	0.57	0.66*
	2-year ave.	0.63*	0.60*	0.74**
Single-crosses	1951	———	0.51	0.80**
Single-crosses	1952	———	0.58*	0.75**
	2-year ave.	———	0.54	0.80**
RPC's	1951	———	———	0.64*
RPC's	1952	———	———	0.76**
	2-year ave.	———	———	0.74**
Height:	1951			
Parents		0.89**	0.74**	0.76**
Single-crosses		———	0.74**	0.84**
RPC's		———	———	0.58*
Leaf rust:	1951			
Parents		0.90**	0.70**	0.78**
Single-crosses		———	0.72**	0.71**
RPC's		———	———	0.84**
Leaf spot:	1951			
Parents		0.89**	0.56	0.90**
Single-crosses		———	0.43	0.84**
RPC's		———	———	0.50

† Parent clones grown in tiller plots.
* r—0.58 for significance at 0.05 level.
** r—0.71 for significance at 0.01 level.

yields. Crosses among the three superior parents were all among the higher yielding single-crosses. MIV-14 and MIV-16 made low yielding crosses with MIV-6 and high yielding crosses with MIV-11 showing the expression of specific combining ability (table 4). This was in the broadcast plots only. There were no significant differences in yield among the single-crosses grown in spaced plantings.

HEIGHT

The association between parents and progenies and among progenies tended to be closer for height than for yield. All

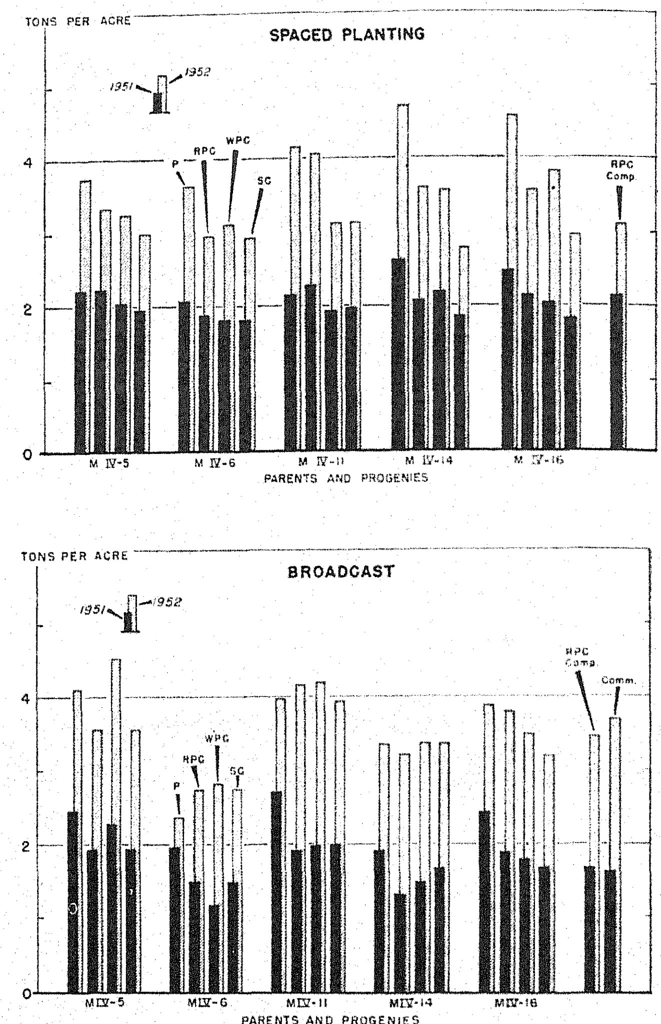

FIG. 2.—Average forage yields from the late maturity group for the parents and progenies. Yields are given for two years and for two methods of planting. The single-cross yields are the averages of all single-crosses for the respective parents.

of the correlation coefficients for height (table 2) were significant (0.05). As with yield, the correlations with the RPC's tended to be lower than the others. There was a correlation between yield and height in 1951. The r values for the early group, late group in broadcast plots and as space planted plots were 0.55, 0.86, and 0.64 respectively. All three were significant (0.01).

DISEASE

Disease ratings were recorded for all plots in 1951. Leaf rust, *Uromyces dactylidis* Otth., and Stagonospora leaf spot, *Stagonospora maculata* (Grove) Sprague, infections were rated on a 1 to 10 scale. Significant differences among entries were found for both diseases. The readings from the broadcast plots showed comparable relationships between parents and progenies and among progenies. The correlation coefficients (table 2) were significant or approaching significance except for single-cross vs. RPC for leaf spot. The r values for leaf spot involving RPC progenies were considerably lower than those relating the other progenies and parents.

Table 3.—Mean forage yields for 2 years of all possible single-crosses among the early maturing parents. Yields are given in tons per acre.

Parents	Parents							
	MI-13	MI-14	MI-16	MI-17	MII-30	MII-34	MII-36	Averages
MI-13	——	2.89*	2.59	2.68	2.92	3.04	2.71	2.80†
MI-14	2.89	——	2.22	2.36	2.65	3.21	2.35	2.61
MI-16	2.59	2.22	——	2.31	3.18	2.91	2.27	2.58
MI-17	2.68	2.36	2.31	——	2.98	2.31	3.40	2.67
MII-30	2.92	2.65	3.18	2.98	——	2.36	2.84	2.82
MII-34	3.04	3.21	2.91	2.31	2.36	——	3.06	2.82
MII-36	2.71	2.35	2.27	3.40	2.84	3.06	——	2.77

* Differences required for significance among crosses are 0.51 (0.05) and 0.68 (0.01).
† Differences required for significance among averages are 0.20 (0.05) and 0.28 (0.01).

SEEDLING VIGOR

Seedling vigor was measured by the production of oven-dry material, height and amount of tillering after 53 days of growth. Table 5 gives the correlation coefficients among the seedling characters and between seedling characters and field performance of the progenies tested. Significant correlations were found for the oven-dry weights of the above ground parts vs. height of the seedlings and tillering in both the early and late maturing groups. Correlations of seedling characters with field performance were not consistent. Seedling vigor as measured by top growth was significantly correlated with yields in the field for the late group tested in broadcast plots but not for the early group or the late group tested as spaced plants.

DISCUSSION

Although some of the parents were found to be highly self-fertile, there was no indication that progeny yields were adversely affected by the self-fertility. In the late maturity group where all progenies were represented as spaced plants, the number of weak plants in the progenies was not consistent with the self-fertility indexes of the parents. Parent MI-13 of the early group that had the highest self-fertility index, 80, would have been expected to produce the most offspring showing reduced vigor due to selfing but its progenies gave the highest yields. Either little selfing occurred under open-pollination or the reduction in vigor due to selfing was compensated for by the more vigorous plants in broadcast plots. In these tests it appeared the selfing potential of the parents was not a factor in progeny performance.

In evaluating the general combining ability of the parents, little difference was found between the effectiveness of the wide polycross and the restricted polycross progeny tests. Because the progenies from the two sizes of polycross nurseries gave comparable evaluations of the parents for combining ability, it seems that the range of pollen available for fertilization is not critical with uniform pollen sources. Having fewer than five entries in a polycross nursery or having the pollen sources confounded, as in a source nursery, might cause varying results.

The average yields of the single-cross progenies from the respective parents were significantly correlated with parental and polycross yields; however, there was considerable

Table 4.—Mean forage yields for two years of all possible single-crosses among the late maturing parents as broadcast plots and space-planted plots. Yields are given in tons per acre.

Parents	Parents					
	MIV-5	MIV-6	MIV-11	MIV-14	MIV-16	Average
MIV-5	—— ——	2.45* 2.68	3.09† 2.68	2.70 2.32	2.75 2.21	2.75‡ 2.47
MIV-6	2.45 2.68	—— ——	2.47 2.45	1.82 2.08	1.74 2.36	2.12 2.39
MIV-11	3.09 2.68	2.47 2.45	—— ——	3.30 2.49	2.99 2.63	2.96 2.56
MIV-14	2.70 2.32	1.82 2.08	3.30 2.49	—— ——	2.23 2.37	2.51 2.32
MIV-16	2.75 2.21	1.74 2.36	2.99 2.63	2.23 2.37	—— ——	2.43 2.39

* Top numbers are yields for the crosses in broadcast plots, bottom numbers are yields as spaced plants.
† Differences required for significance among crosses are 0.44 (0.05) and 0.59 (0.01) for broadcast plots.
‡ Differences required for significance among the averages are 0.22 (0.05) and 0.30 (0.01) for broadcast plots.

Table 5.—Correlation coefficients for the relationship among seedling characters and between seedling vigor and field results.

Characters Correlated	Early Group		Late Group			
	Broadcast		Broadcast		Spaced	
	r	n	r	n	r	n
Top weight of seedlings vs. height of seedlings	0.34*	36	0.91**	22	——	—
Top weight of seedlings vs. tillering of seedlings	.49**	36	.59**	22	——	—
Top weight of seedlings vs. two year average yield in field	−0.18	35	.55**	21	0.08	21
Height of seedling vs. height of second cut in field	− .08	35	.66**	21	——	—

* Significant at 0.05 level.
** Significant at 0.01 level.

variation among the crosses of individual parents. The exhibition of specific combining ability among both groups of parents studied illustrates the importance of considering specific combining ability where only a few parents are to be combined into a synthetic variety. Although the major part of selection can be made from parental and polycross progeny performance, single-cross testing appears to be desirable for final evaluation.

Since the 2 years that the plots were harvested were droughty, the first cutting produced the greater portion of the yield particularly since they were cut at the hay stage. Perhaps cutting earlier to simulate pasturing or removal for ensilage would have lowered the correlations between height and yield. The high heritability of height may have contributed considerably to the relatively high parent-progeny r values.

It was noticed in comparing the various parent-progeny relationships that the correlation coefficients with the RPC's tended to be lower than the others. No explanation is offered for this. Theoretically at least, the correlations between the RPC's and average single-crosses should tend to be higher than the others since with random pollination the RPC's should be a composite of all possible single-crosses.

The results of the experiment with the late group where the parents and progenies were included both in space-planted plots and in broadcast plots show that the two methods may give different evaluations. Parent MIV-14 and its polycross progenies behaved quite differently, compared to the others, in the two methods of planting. For forage yields in particular, broadcast plots should give the more reliable evaluations since grasses are generally seeded in solid stands for forage use.

Progeny testing for leaf spot and leaf rust in orchardgrass may not be necessary; however, such data would ordinarily be obtained in conjunction with yield tests. This data would be a desirable supplement to that obtained from the parents.

It was easier to detect differences in disease susceptibility among the progenies in broadcast plots than in space-plantings. This may have been because the conditions in solid stands were more favorable for the spread and development of the leaf diseases or because it was easier to make comparisons from plot to plot where the plant variation was, in effect, averaged out in the broadcast plots.

In observing the disease resistance of the material, susceptibility to leaf rust was accompanied by resistance to Stagonospora leaf spot and vice versa. High susceptibility to both diseases was not found but some entries appeared to be relatively resistant to both. The nature of the relationship was not studied but it possibly could be a linkage problem. On the other hand, it might have been a physiological reaction with rust infection masking or preventing heavy leaf spot infection even though the material possessed an inherent susceptibility to leaf spot.

The use of seedling vigor tests as a means of evaluating progeny performance should be studied further as a possible short cut in a breeding program. If some way of measuring seedling characters can be devised that will correlate with field response, material could be screened much faster. The relationship between the seedling vigor and the field results of the seeded portion of the late group gave a certain amount of encouragement. The greenhouse tests were conducted in the fall under shortening day lengths. Perhaps a spring or summer trial would give results more consistent with those in the field.

SUMMARY

Methods of evaluating combining ability were studied using seven early and five late maturing orchardgrass clones. Progenies from a wide polycross of 112 clones, restricted polycrosses of the 7 and 5 clones, and single-crosses plus tiller plots of the parents were used in the testing. The early group was planted in broadcast plots and the late group in both broadcast and space-planted plots. Seedling vigor of the progenies as measured by growth in a greenhouse was compared to the field performance.

Considering yield, significant correlation coefficients were obtained in relating polycross and single-cross progenies to the parents, wide polycross progenies to restricted polycross progenies, and 1951 performance to 1952. There was considerable variation among the single-crosses for the respective parents indicating the expression of specific combining ability. The evaluation of the late parents differed in the two methods of planting both through parental yields and progeny yields. It appears that broadcast seedings are more desirable for testing than spaced plantings.

For height, the relationships among the parents and progenies were very similar to yield. Height was significantly correlated with yield.

Differences in susceptibility to leaf diseases were found. Susceptible parents produced susceptible progenies in all cases. Except for the correlations for the restricted polycross progenies for leaf spot, the correlation coefficients among the progenies and parents were highly significant. Differences in susceptibility were more easily detected in broadcast plots as compared to spaced plants.

Significant correlation coefficients were obtained for seedling top growth with seedling tillering and height. Relationship to field performance was obtained only with the broadcast plots of the late group.

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Association Between Diastatic Power and Certain Visible Characteristics and Heritability of Diastatic Power in Barley[1]

A. D. Day, E. E. Down, and K. J. Frey[2]

IT IS a well established fact that diastatic power is a major criterion of malting quality in barley. Diastatic power has been shown to be (2, 4, 7) a strain or varietal characteristic, and therefore, barley breeders can select strains which have a consistent relative activity for this enzyme. One of the major obstacles in selecting barley strains with a desired diastatic power is the lack of an easy method for evaluating this characteristic in the early generations of a barley cross. Even the ferricyanide method for determining diastatic activity in barley grain, developed by Anderson and Sallans (1), it too laborious to be used on the large number of segregates that need to be analyzed in a barley improvement program. Selection for good agronomic barley strains with desirable diastatic activity would be greatly facilitated if an association could be established between certain morphological characters and high or low diastatic power.

Den Hartog and Lambert (3) studied the association between diastatic power and yield, bushel weight, and floret fertility, all of which are considered to be multigenically determined. They found several significant correlations but they were of low magnitude. There is some popular belief that blue aleurone barley varieties are lower in malting quality than white aleurone strains. However, this fact has been refuted by isogenic line studies.[3]

The study reported herein is an attempt to determine if associations do exist in barley between diastatic activity and certain morphological characteristics whose mode of inheritance is known. The morphological characteristics were selected to represent one gene in each of the first five barley linkage groups (6).

MATERIALS AND METHODS

In order to determine if an association existed between diastatic activity and certain visible characteristics known to be determined by a gene which was already mapped, a number of crosses were made between low and high diastatic activity barley varieties in which certain visible characteristics segregated. In each cross, strains of barley homozygous for the two contrasting classes of the particular visible character were selected in the F_3 generation and analyzed for diastatic activity. By comparing the mean diastatic activity of the two classes, it was possible to distinguish any association between a given characteristic and diastatic power. The associations in all cases were with the marker gene rather than the chromosome.

The barley variety, O.A.C. 21, characterized by high diastatic activity, was crossed with a series of varieties having low diastatic power. The parents low in diastatic activity were selected such that when crossed with O.A.C. 21 the resulting progenies would segregate for one monofactorial characteristic gene in each of the first five linkage groups. The barley linkage groups, visible characteristics studied, and crosses representing each linkage group are given in the following table:

Linkage Group	Visible characteristic segregating	Cross
I	2-row vs. 6-row	Alpha × O.A.C. 21
II	Black vs. white hulls	Dorsett × O.A.C. 21
III	Naked vs. covered kernels	C.I. 1370 × O.A.C. 21
IV	Blue vs. white aleurone	O.A.C. 21 × Mars
V	Rough vs. smooth awns	O.A.C. 21 × Mars

Since dominance was involved in each case except 2-row vs. 6-row it was necessary to grow the material in F_3 progeny rows in order to distinguish the 2 homozygous classes of each segregating character. Each plot consisted of 1 row, 16 feet long. The seed harvested from homozygous[4] F_3 rows and parental selections, which were also grown in 1-row plots, 16 feet long, was ground to pass through a 20-mesh sieve and diastatic activity was then determined on each sample according to the method of Anderson and Sallans (1). Each sample was analyzed in duplicate or until the determinations agreed on titration to within 0.3 ml. of sodium thiosulphate. A standard variety was included as a check with each set of determinations. The difference between the mean diastatic activity of the two homozygous classes of segregates from a cross was tested for significance by a "t" test.

In order to compare naked with hulled barley seed the means of the *naked kernel* parent and the *naked kernel* progenies were adjusted for hulls using 13 as the average percentage of hull on a 6-row barley (8).

RESULTS

Association of Diastatic Power and Visible Characteristics

The means of diastatic activity in degree Lintner (L°) and the "t" values for each of the progeny classes and the parents are given in table 1. In all five cases the parents differ significantly in diastatic activity, with O.A.C. 21 being the highest in each comparison. It is evident from the "t" test for progenies that there is an association between diastatic activity and the 2-row vs. 6-row characteristic. However, the progeny of the 2-row group had the highest mean diastatic activity, in contrast to expectation. If some genes in linkage group I of the O.A.C. 21 parent contributed to high diastatic activity, it would be expected that the segregates of the 6-row group would have a higher mean diastatic activity than the 2-row group. To explain the results obtained, it must be assumed that the chromosome which carries the 2-row gene in the Alpha parent contributes a great deal of diastatic activity while the comparable chromosome in O.A.C. 21 contributes relatively little. The average background of germ plasm in the two classes of progeny should be approximately equal and any difference between the two groups in diastatic activity would be the contribution from

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[3] Personal communication from Dr. G. A. Wiebe.

[4] "Homozygous" refers only to the gene being studied.

Table 1.—Diastatic power in L° of parental varieties and classes of segregates from several barley crosses.

Generation	Chromosome group									
	I		II		III		IV		V	
	Alpha × O.A.C.21		Dorsett × O.A.C.21		O.A.C.21 × C.I.1370		O.A.C.21 × Mars		O.A.C.21 × Mars	
	2-Row	6-Row	Glumes		Kernels		Aleurone		Awns	
			Black	White	Covered	Naked	Blue	White	Rough	Smooth
Parents*										
N	12	12	12	12	12	12	12	12	12	12
M	183.06	215.13	163.89	215.13	215.13	186.20	215.13	141.15	215.13	141.15
t	3.37**		5.61**		3.41**		8.58**		8.58**	
Pure Breeding Progeny										
N	30	30	30	30	5	5	33	30	32	31
M	211.09	166.48	163.42	169.36	145.73	150.71	143.17	151.32	151.29	128.44
t	6.10**		0.85		0.55		1.37		3.12**	

* N = Number of selections or lines analyzed.
M = Mean.
t = t-value of the "t" test.
** Significant at the 1% level.

genes located in linkage group I. This can be illustrated by arbitrarily assigning numerical values for diastatic power to the genes in each parent. If it is assumed that the genes in linkage group I of O.A.C. 21 contribute 10 L°, the genes for diastatic activity in linkage group I of the Alpha parent contribute 55 L°. In this case the expected diastatic activity in progeny of the 2-row group would be 211 L° and the diastatic activity of the 6-row group would be 166 L° which fits exactly the values obtained. Irrespective of the validity of this explanation the data show that genes for determining diastatic activity are very definitely found in linkage group I in the Alpha × O.A.C. 21 cross.

As indicated by the "t" test, no association of diastatic activity was found between black vs. white hulls, covered vs. naked kernels, or blue vs. white aleurone. Since the number of progenies involved in the covered vs. naked kernel comparison were very small, this was not a critical test. The absence of association in linkage group IV is very interesting because there is a belief among some maltsters and brewers that white aleurone barley varieties are better for malting quality than blue ones. The data in this study would at least indicate that the malting quality characteristic, diastatic power, is not one of those which is associated with either blue or white aleurone. If malting quality is associated with this characteristic some criterion other than diastatic power must be responsible.

The data in table 1 indicate that there is an association between diastatic power and the rough vs. smooth awn characteristic in linkage group V. The rough awn class has a higher mean diastatic activity than the smooth. This would be expected if the O.A.C. 21 linkage group V carries genes for high diastatic activity.

The data given here indicate that there are genes in linkage groups I and V which contribute to high diastatic activity of barley. It may be found in other sets of crosses that there are also associations between genes in linkage groups II, III, and IV and diastatic power. However, in the crosses involved here no such association was obvious. If the genes determining diastatic activity work on a straight additive basis, we must assume that either a large portion of these genes are located in linkage groups VI and VII which were not investigated in this study, or the genes contributing to diastatic activity were similar in the parents involved in the studies of linkage groups II, III and IV. According to the data presented the average contribution of linkage group V to diastatic power in the O.A.C. 21 parent was 23 L°, if the contribution from the Mars variety is considered to be zero. This figure represents a sizable part of the diastatic activity of O.A.C. 21.

Heritability of Diastatic Power

The heritability values for diastatic activity of the barley grain are given in table 2. They correspond to what Lush (5) describes as being in the "broad sense." In other words the genetic variance obtained by subtracting the mean parental variance from the total progeny variance contains not only additive genetic effects but also those due to dominance and epistasis. However, since the data used herein were collected from F_3 progenies the epistatic and dominance effects were materially reduced from the usual case when this method is applied to the variability among F_2 plants. The following formula was used in determining the heritability percentages:

$$\text{Heritability \%} = \frac{\text{Variance of progeny} - \text{Mean variance of parents}}{\text{Variance of progeny}} \times 100$$

In the crosses which showed no significant differences in diastatic power between the two selected classes, all of the strains were used as a random sample in the calculation of the heritability percentage. However, in those crosses showing a significant difference in diastatic power between two

Table 2.—Heritability percentages of diastatic power in barley.

Cross	Total variance	Genetic variance	Heritability %
O.A.C. 21 × Mars	676	231	34.2
Dorsett × O.A.C. 21	720	220	30.6
Alpha × O.A.C. 21	802	361	32.5
Mean	—	—	32.4

selected classes, it was necessary to calculate the variance within each class and then pool them in order to find the heritability percentage. Such was the case with the rough and smooth awn types in the O.A.C. 21 × Mars cross. Otherwise, there would have been introduced an artificial variance created by the differences between the means of the two classes. This method of analysis may lead to an underestimation of heritability since the complete range of variability of the linkage group in which selection is practiced does not enter into either class.

The heritability percentages for diastatic power ranged from 30.6 to 34.2 in the three barley crosses with a mean of 32.4. These values are not extremely high but, nevertheless, they do indicate that considerable progress could be made in selecting for high diastatic power among barley strains in the F_3 generation. Also worthy of note is the uniformity of the heritability percentages from the different crosses. Generally heritability values calculated by this method are not so consistent.

DISCUSSION

Barley data presented herein indicate that it should be possible to select strains early in the improvement program with certain morphological characteristics with assurance that the selected lines will be better for diastatic activity than a random sample. Such was the case in rough vs. smooth awn in the O.A.C. 21 × Mars cross, where the rough awn class of segregates had a mean diastatic activity significantly higher than that of the smooth awn class. (However, there are enough smooth awn commercial varieties to show this does not exclude the possibility of developing a smooth awn variety with desirable diastatic power.) In a cross between rough and smooth awn varieties, knowledge of the diastatic activity of the parents would tell the breeder whether to select rough or smooth awn segregates to obtain a favorable ratio of high diastase types. Of course, association demonstrated between diastatic power and the rough vs. smooth awn character might work to the breeder's disadvantage if it were desired to combine the smooth awn character from a low diastase parent with the high diastatic activity from a rough awn parent.

The association between the 2-row vs. 6-row character and diastatic power is of very little importance to barley breeders in the North Central States since the maltsters in this region prefer the faster germinating 6-row types. However, such an association could be very important to European barley breeders where the predominant malting type is 2-rowed. Thus, the association between the 2-row vs. 6-row character and diastatic power would be equally useful whether a 2-row or 6-row variety were desired, particularly if the association were one of relatively close linkage rather than pleiotropy.

Before any set rules can be established for barley breeders, relative to the association between known morphological characteristics and the association with diastatic activity, it will be necessary to run more linkage studies such as the one reported here. It may be found with future studies that the determination of diastatic activity is very closely allied with only a few of the seven linkage groups known in barley. Also, any future study should probably be conducted with different genes from those used herein, since it may be possible to miss linkages which actually exist. If the segregating characteristic were determined by a gene located near the end of a chromosome and a gene or genes for diastatic activity were located at the opposite end the two would probably appear to segregate independently.

SUMMARY

In a study to determine whether there was any association between diastatic activity in barley grain and known morphological characteristics, it was found that diastatic activity was associated with the rough vs. smooth awn character determined by a gene located in linkage group V. No associations were found between diastatic activity and the black vs. white hulled character determined by a gene in linkage group II, the naked vs. covered kernel character of linkage group III, or the blue vs. white aleurone character of linkage group IV. There was an association between diastase activity and the 2-row vs. 6-row characteristic determined by a gene in linkage group I. Of unexpected occurrence was the fact that the 2-row segregates had a significantly higher mean diastatic power than the 6-row types. Heritability values ranging from 30 to 34% were obtained for diastatic power .

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Pfeffer's Studies of the Root Growth Pressures Exerted by Plants[1]

William R. Gill and G. H. Bolt[2]

THE pressure exerted[3] and work performed by roots during growth are important considerations in evaluating the effect of soil physical properties on plant growth. Data on experiments to measure such pressures appear in a paper by W. Pfeffer, "Druck und Arbeitsleistung durch Wachsende Pflanzen" published in *Abhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften,* 33:235–474, 1893. Since this paper is absent from American soils literature the following review is presented to add to the data and to stimulate further interest in such measurements.

The basic principle of Pfeffer's measurements of root pressure was to encase a portion of the root of a seedling plant in a plaster of Paris block in order to provide a base against which the growing root could exert pressure to move a second block that was cast around the exposed tip or side of the root. Movement of the second block would compress a calibrated spring providing a measure of root elongation or expansion and the pressure exerted by the root. Figure 1 shows the arrangement of Pfeffer's apparatus.

Measurement of Axial Root Growth Pressure

To determine the axial pressures of growing roots with this arrangement, (figure 1 (a)), a pot P filled with moist excelsior M, was fastened to a stand S. The lower portion of the root was embedded in a plaster of Paris block A which was anchored securely by the plaster of Paris collar, which extended into the pot through the bottom hole, as shown by the white oval area in the pot. The root tip R extended through block A into a shallow hole in a second plaster of Paris block B. Block B was firmly secured to a glass disk D which was in turn connected with the stand S through compression spring F. The adjustment of screws E permitted the adjustment of the initial tension in the spring F. Two indicator needles I were mounted on the spring to permit a direct measurement of the compressed spring with the aid of a cathetometer.

To prepare a plant for axial pressure measurement, a seedling was placed in the pot filled with excelsior with the root extended 15 to 30 mm. through the bottom hole. The pot was then inverted and a paper cylinder with a radius of about 1 cm. placed around the root. The height of the cylinder was cut so that approximately 5 to 8 mm. of the root still extended above the cylinder. A plaster of Paris mixture was poured into the cylinder, flowing down into the pot through the bottom hole forming a collar within the pot to bind block A to the pot. Then a glass plate, with a hole comparable to the size of the root, was covered with wax paper and pressed over the root tip, permitting the tip to extend upward through the glass and paper. When block A was hard, the glass and paper were removed and replaced by a very thin piece of paper similarly provided with a hole. The plaster of Paris block B was poured on top of this paper, thus separating blocks A and B by a very small gap G, corresponding to the thickness of the thin paper. Results of measurement of axial root growth pressures secured by this method are given in table 1.

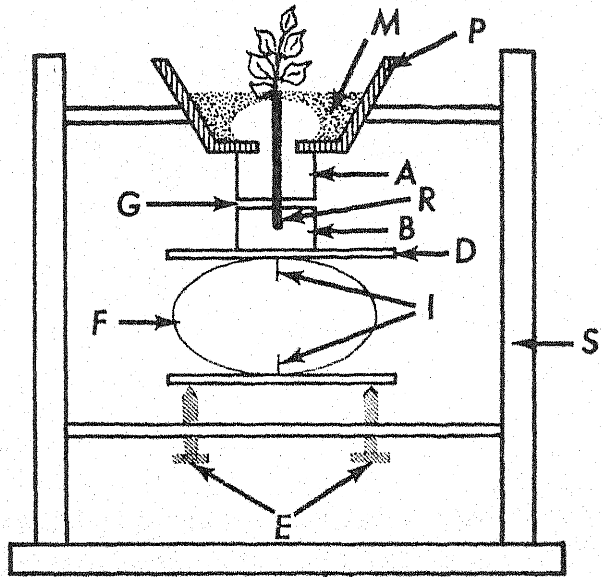

Fig. 1(a)
Pfeffers' apparatus for measuring axial root pressures

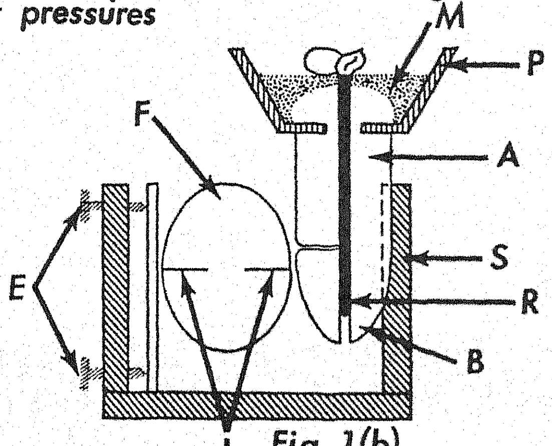

Fig. 1(b)
Pfeffers' apparatus for measuring radial root pressures.

FIG. 1.—(a) Pfeffer's apparatus for measuring axial root pressures. (b) Pfeffer's apparatus for measuring radial root pressures.

Measurement of Radial Root Growth Pressure

Radial pressure measurements were performed with a modification (figure 1 (b)) of the original apparatus. In this case the plaster of Paris block A not only surrounded the upper part of the root but also laterally enclosed half of the lower part of the root throughout the length of the root. Results of radial root growth pressure measurements secured with this apparatus are shown in table 1.

Pfeffer's Discussion of Pressure Measurements

Pfeffer believed that roots are a proper subject for pressure studies with plants since they do not require light and exert pressure on objects in the growth medium.

[1] Received for publication Sept. 29, 1954.

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[3] The term "root pressure" should be avoided in this case since this term is presently applied by plant physiologists to a different phenomenon. The roots of some plants absorb water from the soil and exude it into the stems under pressure independent of any transpiration effects by the upper portion of the plant. This pressure has been termed "root pressure" and is used extensively in the botanical literature. As a suitable term "root growth pressure" is suggested which may be accompanied by such adjectives as axial and radial.

In order to reach maximum values in the axial direction, a root must be securely anchored and completely confined in the radial direction. In nature this could not always be true; hence a bending of the root instead of a buildup of axial pressure might occur. For this reason, pressures recorded in table 1 were considered as the maximum values since both side support and enchorage in the experiments were of sufficient magnitude.

Pfeffer believed that plaster of Paris blocks had no bad effect on root growth. To determine the effect of aeration on root growth under his conditions, he sealed a root in a plaster of Paris cylinder from which all oxygen was removed, and found that it maintained the same growth rate over a 24-hour period as a root in water containing oxygen.

The method of calculating the pressure was based on effective root area determined by measuring the cross section in the hole of the block. This is shown as the area of the root in table 1. Over an extended period, lateral growth would take place between the two blocks. This larger root cross section was the area shown under experiments lettered B in table 1. Coupled with the spring compression, the area provided the means to calculate the root pressure. Table 1 indicates that roots exerted pressures of 10 atmospheres or more when resistance was present on all sides. Pressures were exerted in both radial and axial directions, but rates of pressure buildup were not the same in the two directions. Axial pressure appeared greater than radial pressure. A relationship was believed to exist between them since experiments 5A and 5B indicated that radial pressure buildup would increase materially if the axial growth was impeded.

As the root met an external resistance, data indicated that the pressure would build up approximately asymptotically to a constant value. Since the total effective area in the radial direction greatly exceeded that of the axial direction area, the total force exerted in the radial direction under natural conditions would be many times larger. This is evidenced by the splitting action of roots in cracks in rocks, etc.

Mechanism of the Pressure Development

Pfeffer considered osmotic pressure in a free cell to be entirely balanced by wall pressure. If, on the other hand, the cell were confined by other tissues or external pressures, osmotic pressure would then be balanced by wall pressure plus external pressures. If the cell were to exert maximum pressure on its surroundings, the wall pressure would have to be reduced to zero. Data showed that actual pressure build-up by roots, could be increased by either a release of wall tension through growth of the cell walls or by an actual increase in the osmotic concentration within the cell. In a very thin cell wall, Pfeffer believed that actual growth did not contribute to the pressure, but merely permitted a transfer of internal pressure to external resistance. He considered that, if the turgor pressure were fully balanced by the exterior resistance and growth continued, there could be a folding of walls within the root. This folding would not be inhibited by the turgescent condition of the cell.

To determine if the plaster block influences the osmotic concentration of a root, Pfeffer grew roots of seedling plants in plaster of Paris and in excelsior. Results showed that the osmotic concentration of the cells of beans grown in plaster of Paris increased, while those of corn did not. It would then appear that both of the mechanisms could be effective in some plants.

The actual measurement of the turgor pressure of the root cells was determined by the plasmolytic method. Roots were placed in a series of KNO_3 solutions immediately after taking them from the growth medium. Incipient plasmolysis as estimated by microscopic length measurements was used as the criterion of turgor pressure measurement. Additional evidence that the pressure development was brought about through growth of the cell wall was supplied by placing corn roots in a plaster of Paris block with one side exposed. If the root was placed in a solution of KNO_3 at this time, the tip shrank away from the block. If on the other hand, the root remained in the plaster of Paris 2 or 3 days before it was placed in KNO_3, it would not shrink away. When it was removed and placed in water, a swelling took place, always more pronounced closer to the tip where the new cells would have formed by cell division, but which would only need to elongate. This was interpreted to mean that growth had taken place to prevent the root from shrinking since it had already shown the osmotic concentration did not increase in corn when embedded in plaster of Paris. In order to separate swelling from growth when the tissues were placed in water, the water was kept near freezing to prevent growth. Results of these experiments are shown in table 2.

Table 1.—Axial and radial pressures developed by roots.

Experiment No.	Axial Pressures				Radial Pressures				
	Duration of Experiment	Distance from tip	Cross sectional area of root	Pressure developed	Duration of Experiment	Condition of the root tip	Effective zone of root. Location and length	Lateral area	Pressure developed
	hours	mm.	mm.^{2}	atm.	hours		mm.	mm.^{2}	atm.
					Faba vulgaris				
1	70	6.2	3.4	7.04	167	Confined	0–8	29	6.11
2	72	5.0	3.7	7.70	120	Confined	0–5.5	10.5	4.61
3	36	4.0	3.7	10.67	168	Confined	0–5	7.5	6.11
4	192	3.5	2.6	9.70	144	Confined	0–6.6	12.2	4.30
5A	94	0.0	1.13	19.36	164	Confined	7–15.7	15.8	5.50
5B	94	4.8	2.01	10.44	237	Free–7.5	------	17.1	3.90
					Zea mais				
6A	71	2.6	1.13	24.94	118	Free–7.5	0–11.2	11.0	6.59
6B	71	2.6	2.52	11.18	—	—	—	—	—
7A	34	2.3	1.54	12.39	—	—	—	—	—
7B	34	2.3	2.00	9.53	—	—	—	—	—
					Vicia sativa				
8A	94	2.2	0.31	13.33	—	—	—	—	—
8B	94	2.2	0.5	8.26	—	—	—	—	—
					Aesculus hippocastanum				
9	117	3.2	4.9	6.65	—	—	—	—	—

Table 2.—Growth of *Vicia faba* roots in gypsum casts.

Root	a*			b*	
Zone observed (tip = zero)	Mm. 2–5.66	Mm. 5.66–10.69	Mm. 10.69–15.14	Mm. 17–5.16	Mm. 5.16–9.55
Length before encasing in gypsum	127	117	103.5	116	102
Length in 6% KNO_3 after 54 hours in gypsum	126	116	103.5	116	102.5
Length in water	143	122	104.0	136	106.5
Length when returned to 6% KNO	126	116	103.5	116.5	102
	%	%	%	%	%
Shrinkage	11.9	4.9	0.48	14.7	3.9

* Different roots.

It was thus shown that the external pressure resulted from the release of tension in the cell walls. Because pressure build-up was dependent on the growth of the cell wall, the pressure build-up against exterior resistance was a slow process, and maximum values could conceivably be reached only after 2 or 3 weeks. In general, a high percentage of the maximum value was reached in 2 or 3 days.

Growth Rate Against External Resistance

When a root was grown against a resistance, the rate of growth was found to be zero until the cell tension had been released sufficiently to overcome the resistance. After this point, the growth rate in general was found to be constant and, up to a certain point, independent of the magnitude of the external resistance. This period of building up, during which the wall tension was released, could be seen as an induction period. The existence of such an induction period made later measurements of the work performance rather difficult.

Exterior Work Performed by a Growing Plant

Since work performed results from the application of force over a distance, its value would be zero when either the force or the distance was zero. A plant growing in a medium such as water without resistance would exert zero force, while the distance would become zero if the exterior resistance was higher than the maximum pressure developed by the root. The root would perform work at intermediate values of the exterior resistance. A maximum work value was believed to occur at a point probably between one-half and two-thirds of the maximum resistance which could be overcome by the root. It was noted that the growth rate, at lesser values of exterior resistance was by no means proportional to the external resistance which probably accounted for a rather sharp maximum in work performance.

To measure work performance, root growth was followed in a homogeneous plastic medium of clay or gelatin in which different external resistances were made possible by variation of the moisture content. Resistance of the medium was evaluated by a penetrometer with a tip similar in shape to the root. Data are shown in table 3.

The rate of root growth in the slurry having a resistance of 1 gram was comparable to the rate of growth in water. The physical resistance of the clay was considered the important factor in root growth since Pfeffer believed aeration was equal in both cases. Considering that the root would not elongate until its induction period was complete, Pfeffer recalculated his data. In the axial pressure measurement investigations, bean roots required 6 to 7 hours to build up pressure against 100 gms. If this induction period was subtracted from the growth time, the theoretical increase could be added to the roots grown in the clay, enabling a comparison of growth on a 24-hour basis. The length of 12.9 mm. taken from table 3 when multiplied by the factor 24/18 in the case of a 6-hour induction period gave a calculated growth of 17.2 mm. which was essentially the same as that of the root in the slurry where no induction period occurred. The total work done by the root indicated in table 3 was 17.4 gm mm in the slurry and 1,290 gm mm in the 18.3% clay. As a comparison, burning ¼ mgm. starch would be equivalent to 1 calorie or about 42,000 gm mm equivalence of work. Thus the work performed by the root in this case was very small and would require only a small part of 1 mgm. of starch.

Table 3.—Influence of external resistance on rate of growth and work performance.

	Moisture content of a homogeneous clay	
	18.3 Percent	Slurry
Soil resistance to penetrometer	100 gms.	1 gm.
Growth of roots in 24 hours	12.9 mm.	17.4 mm.
Work performed (force × distance)	1290 gm.mm.	17.4 gm.mm.

Pfeffer considered that in nature a plant would deviate from its path in coarse-grained soils to go around solid resistance; thus the pressures exerted by a root would be less than pressures measured with a penetrometer. In fine-grained homogeneous mediums, the relationship between root penetration and penetrometer results appeared to be quite good.

Stem Growth Pressures Developed by Grass

Modifications of the apparatus shown in figure 1 were used to determine pressures exerted by other parts of the plants. In general, the results showed that axial pressures of the stems were of the order of magnitude of 7.5 atmospheres and radial pressures were about 5.5 atmospheres. The static moment of nodes ranged from 120 gm cm to 500 gm cm.

Conclusions from Pfeffer's Study of Pressures Developed by Growing Roots

Pfeffer's elaborate and well conducted experiments show the magnitude of pressures exerted by plant roots against external resistances encountered in the soil. These values form the only set of data available at this time.

Since the root has plastic properties, its path will generally be along the line of least resistance. Therefore, high values of axial pressures exerted are only encountered if the root is sufficiently confined in its radial directions.

The observation that wrinkling or folding of the cell walls of the root takes place when the root encounters unsurmountable external resistance suggests a possible diagnostic method of interpreting impeding properties of the soil in terms of the plant itself.

The calibration of homogeneous plastic media with a penetrometer for the evaluation of root growth against resistance appears to be another worthy line of approach.

The Response of Four Varieties of Alfalfa to Spring Clipping, Intervals Between Clippings, and Fall Clipping in the Yakima Valley[1]

J. A. Jackobs and Donald L. Oldemeyer[2]

SEVERAL investigators (1, 2, 4) have shown spring-clipping, frequent cutting, and cutting at certain critical periods in the fall to be detrimental to alfalfa in the Mid-western states. However, the results of a management study reported by Jackobs (3) indicated that such management practices have little or no effect on the vigor and productivity of irrigated alfalfa in the Yakima Valley in south central Washington. The climate in the Yakima Valley is characterized by low rainfall and high light intensities; the ability of alfalfa in that area to withstand management treatments that are detrimental in the Midwest may be due to differences in such climatic factors and differences in soils.

Since Ladak was the only variety used in the initial study in the Yakima Valley, the question arose whether or not the results would be the same with other varieties. Results of such a study are reported here.

MATERIALS AND METHODS

A field on the Roza Unit of the Irrigation Experiment Station, Prosser, Wash., was selected for this experiment. The soil is Ritzville very fine sandy loam and varies in depth from 4 to 6 feet. The field was first irrigated in 1946, and the following crops were grown: 1946, lima beans; 1947, sweet corn; 1948, navy beans on one half of the field and vetch on the other.

Alfalfa was seeded May 5, 1949. The two replicates located where navy beans were grown in 1948 were successfully established, but the seeding following vetch failed and was replanted on Aug. 24, 1949.

The field was irrigated about once a month, using 24-hour applications of water in rills 3 feet apart. A 2½-inch stubble was left when a plot was cut. Yields were determined from a mower swath cut through the middle of the plot. All yields are given on an air-dry basis.

Main plots, 30 by 60 feet, consisted of 6 treatments including 3 cutting intervals both with and without spring clipping. Sub-plots consisted of 4 varieties of alfalfa: Ladak, Buffalo, Turkistan 19300, and Ranger. On Oct. 10 one half of each variety sub-plot was cut. The treatments within each division were randomized and there were four replications.

The cutting schedules were so arranged that the spring-clipping was made on May 1. Plots cut at 25-day intervals were cut first on May 26; the 30-day interval plots on June 1; and the 40-day interval plots on June 9. In this way the 5th cutting of the 25-day interval treatments, the 4th cutting of the 30-day interval treatment, and the 3rd cutting of the 40-day interval treatment all fell on Aug. 30. The late fall harvests were made on Oct. 10.

The cutting schedules outlined above were followed in 1950 and 1951. In 1952 all plots were cut on the same date at each of 3 cuttings. Differences in yield obtained in 1952, with the exception of those due to variety, are considered to be due to the residual effects of the previous management treatments.

At the conclusion of the experiment, stand ratings were taken by counting the number of crowns falling under a 16-foot transect.

[1] Scientific Paper No. 1361, Washington Agr. Exp. Sta., Pullman, Wash. Project 967. Rec. for publication Oct. 18, 1954.

[2] Associate Professor, University of Illinois, Urbana, Ill., formerly Assistant Agronomist, Irrigation Exp. Sta., Prosser, Wash.; and Plant Breeder, Amalgamated Sugar Co., Nyssa, Oreg., formerly Assistant Agronomist, Irrigation Exp. Sta., Prosser, Wash., respectively.

EXPERIMENTAL RESULTS

The yields of the four varieties of alfalfa with the various management treatments are given in table 1. An analysis of variance indicated that there was only one significant interaction in the course of the experiment between spring-clipping and interval-between-cutting in 1951.

SPRING CLIPPING

Clipping alfalfa on May 1 in 1950 and 1951 definitely decreased seasonal yield even though the weight of clipping was included. However, spring clipping did not appear to reduce plant vigor permanently, because in 1952, the plots that were spring-clipped in 1950 and 1951 produced within 0.35 ton per acre of those that had not been spring-clipped—a nonsignificant difference.

INTERVAL BETWEEN CUTTINGS

Increasing the number of cuttings per season from 3 to 4 and from 4 to 5 reduced seasonal yields an average of 0.77 and 0.96 tons per acre respectively. The 1952 yield data, however, did not indicate an appreciable reduction in plant vigor due to frequent cuttings.

FALL CUTTING

In 1950 an average yield of 0.40 ton of hay per acre between Aug. 30 and Oct. 10 increased the seasonal yield by this amount. In 1951, yields of the two treatments were nearly equal, indicating that the harvest in October compensated for the reduction caused by late cutting the previous fall. The 1952 data indicate a small but statistically significant reduction in plant vigor from cutting late in the fall. Plots cut late in the fall of 1951 yielded 0.23 ton per acre of hay less in 1952 than those not cut after Aug. 30.

VARIETIES

When the various cutting treatments were repeated in 1951, there were significant differences among varieties. Ladak, the check variety, produced less than the other varieties. The difference between Ladak and Turkistan only approached significance.

SPRING-CLIPPING × INTERVAL BETWEEN CUTTING INTERACTION IN 1951

The difference between the spring-clipped and check plots in 1951 was not the same for different cutting intervals. Table 2 shows the yields of the six cutting treatments and the difference in yield between spring-clipped and check plots. It is apparent that the difference is much smaller when there was a 40-day interval between cuttings than when the interval was 25 or 30 days.

EFFECTS UPON STANDS

Ratings of the stands in the fall of 1952 showed no detrimental effect resulting from the management practices. Full stands remained throughout all the plots.

Table 1.—Seasonal yields of four varieties of alfalfa under various cutting treatments at the Irrigation Experiment Station, Prosser, Wash., Tons of air-dry hay per acre.

Variety	Spring clipped	Not spring clipped	Interval between cuttings, in days			Fall cut	Not fall cut	Var. av.
			25	30	40			
				1950				
Ladak	6.01	7.19	5.63	6.70	7.47	6.74	6.46	—
Buffalo	6.56	7.68	6.11	7.13	8.12	7.40	6.84	—
Turkistan	6.34	7.39	5.84	7.04	7.72	7.11	6.62	—
Ranger	6.17	7.38	5.98	6.74	7.61	7.02	6.52	—
Average	6.27	7.41	5.89	6.90	7.73	7.07	6.61	—
				1951				
Ladak	5.49	6.15	5.14	5.61	6.72	5.84	5.81	5.82
Buffalo	5.83	6.77	5.59	6.14	7.18	6.32	6.29	6.30
Turkistan	5.55	6.56	5.25	5.79	7.07	6.05	6.02	6.03
Ranger	5.80	6.55	5.49	6.04	7.00	6.24	6.12	6.18
Average	5.67	6.51	5.37	5.90	6.99	6.11	6.06	—
				1952				
Ladak	5.98	6.31	6.22	5.96	6.26	6.09	6.18	6.14
Buffalo	5.91	6.29	6.14	6.14	6.06	5.95	6.26	6.10
Turkistan	5.82	6.23	5.94	6.02	6.14	5.84	6.22	6.03
Ranger	6.10	6.38	6.12	6.16	6.45	6.15	6.32	6.24
Average	5.95	6.30	6.10	6.07	6.23	6.01	6.24	—

DISCUSSION

In general, the results substantiate the previous work reported by Jackobs (3) in which only one variety was used. The main differences were the more pronounced effect of spring clipping and a smaller effect from fall cutting. Hay yields of the alfalfa were materially reduced by the more frequent cuttings during the seasons in which the clipping treatments were applied.

In 1951, the second year of differential management, yields of the fall-clipped plots were about the same as from those that were not fall-clipped. Apparently fall cutting causes reduced yields during the early part of the following season. However, this was compensated for by the yield obtained from the late cutting. The late fall clipping treatment did cause a significant reduction in yield in 1952 when all plots were harvested on a three cutting schedule. The additional yield from a fall cutting was not included in the seasonal yield, and there was no compensation for the lower yields in the early part of the season.

The significant interaction of spring-clipping × interval between cuttings for yield might be expected. With the 40-day interval, there was a longer period for the replenishment of root reserves before plots were cut the second time. Consequently, the reduction in subsequent yields was less.

Reductions in yields because of the treatments could be attributed mainly to depleted root reserves and not to a permanent reduction in plant vigor. No significant residual effects were found in 1952, except for the fall cutting treatment. No effects upon stand were noted.

SUMMARY

Four varieties of alfalfa were grown for hay production under various clipping schedules which included spring clipping; 25-, 30-, and 40-day intervals between cuttings; and fall clipping. The schedules were arranged so that the date of the last cutting of all plots, except the fall cutting, was Aug. 30. The treatment schedules were followed in 1950 and 1951. In 1952, all plots were harvested uniformly with three cuttings to measure any residual effects that resulted from previous treatments.

Significant reductions in yield resulted from more frequent clipping. In 1951, the average seasonal yield for the 25-day interval of clipping without a spring-clipping was 5.90 tons per acre as compared with 7.13 tons per acre for the 40-day frequency without spring-clipping, a reduction of over 1 ton per acre by cutting 5 times rather than 3.

By adding the spring clipping treatment to the 25-day interval, the yield was further reduced to 4.83 tons per acre. With the 40-day interval, the yield was 6.85 tons per acre. Spring clipping caused significant reductions in yield, with the effect being more pronounced with the shorter interval between clippings. This interaction was significant.

No significant effect of fall clipping on seasonal yield was found until 1952, the year following the discontinuance of the treatments. The fall clipping in 1950 did not influence yields in 1951, but the treatments did give a significant reduction in 1952 when all plots were treated alike.

Significant differences among varieties were obtained only in 1951, and no variety × treatment interactions were found. The only residual effect due to treatments was that of fall clipping.

Table 2.—Interaction of spring clipping × interval between cuttings. Yield in tons per acre.

Interval between cutting (days)	Spring clipped	Not spring clipped	Difference
25	4.83	5.90	1.07
30	5.33	6.46	1.13
40	6.85	7.13	.28

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Response of Soybean Strains to 2,4-D and 2,4,5-T[1]

H. A. Fribourg and I. J. Johnson[2]

DURING the past 5 years a series of investigations has been conducted at the Iowa Agricultural Experiment Station to determine the differential response of a wide range of genotypes in corn, oats, and soybeans to several growth regulating compounds. These studies have been made in the laboratory using the root suppression test and in the field with standard spray techniques. Results of these studies, including the cytohistological effects of 2,4-D on apical meristem of oats and the inheritance of differential response to 2,4-D in corn, have been published (1) (3) (4) (5) or are currently in press. Many studies have been reported, largely in the abstracts of the North Central Weed Control Conference, on varietal response of crop plants, using varieties or hybrids that are commercially grown, to determine tolerance limits for chemicals now used as herbicides.

The present investigation with soybeans, however, was designed as an exploratory study to determine (from an agronomic point of view) the differences that might exist among a group of introductions from the Orient. It was believed that this source of material, from which present soybean varieties originated either as selections or from crosses among these selections, might represent a wider range in genetic diversity than could be found among more recently developed varieties adapted in maturity to the cornbelt. Discovery of even a few strains with a relatively high degree of tolerance might therefore prove to be of value to the soybean breeder as parents for use in developing agronomically desirable strains that could tolerate dosage rates effective in selective weed control. Such strains might also be of value to the physiologist for further studies on the causes of injury to plant tissues by growth regulators.

An attempt also was made in this study to determine the relationship between the response to 2,4-D of strains tested in the seedling stage under greenhouse conditions using the single droplet technique (2) and their field response to spray application of 2,4,5-T as measured by reduction in seed yield. Previous studies with soybeans[3] had shown a poor relation between the root suppression test and field response to 2,4-D as measured by dry weight of leaves. Rapid tests to screen a large number of selections for differential response would be a valuable aid in a breeding program.

MATERIALS AND METHODS

From among nearly 2,000 introductions available[4] from the Orient, a group of 200 was chosen to represent a cross-section from China, Manchuria, Korea, and Japan within the maturity range adapted at Ames, Iowa. An attempt was made to increase the limited seed during the winter, 1951–52 in cooperation with the U. S. Department of Agriculture field station at Brawley, Calif., but failed due to severe freezing temperatures. An increase was successfully made in 1952 at Ames, Iowa, and at Columbia, Mo., in cooperation with the Regional Soybean Laboratory. Among the original 200 strains, 16 were too low in germination to provide adequate seed.

Screening tests with the micro-droplet technique were made in the greenhouse during the winter, 1952–53 using only 2,4-D since 2,4,5-T could not be effectively used on soybeans. Soybean seedlings do not show a marked response when treated with 2,4,5-T using the micro-droplet technique. After a large number of preliminary studies to determine optimum concentrations, wetting agents, solvents, manner of application and methods of evaluating effects, the following procedure was adopted.

Five soybean seeds per strain were planted in a soil-sand mixture in each of three 4-inch clay pots previously coated externally to reduce moisture evaporation. After the seedlings had emerged to full unifoliolate leaf stage and the central leaflet of the first trifoliolate leaf was almost fully expanded and before the second trifoliolate leaf had begun to unfold, all seedlings not at this stage of growth were removed by cutting at the soil surface. If available, one seedling at this exact stage of growth was left per pot. Of the three pots per strain, one was designated as the check and the remaining two each were treated with a micro-droplet (0.013 to 0.014 cc.) of an aqueous solution containing 5% tergitol and 50 and 100 ppm. concentration respectively acid equivalent of 2,4-D. The single droplet was placed near the mid-rib of the central leaflet midway between the base and the tip. Plants were then permitted to continue growth at greenhouse temperatures of 70 to 75° F. for 2 weeks, or until the fourth trifoliolate leaf was expanding. The effect of 2,4-D treatment was recorded as a percentage reduction in leaf size by visual comparison with the check for each of the first (treated), second and third trifoliolate leaf. Greatest reduction usually occurred to the second leaf; rarely did it extend to the fourth leaf. To facilitate routine testing, 20 strains were included in a group and one replication (3 pots) of each planted every third day. A total of 40 strains were tested in 10 replications before high greenhouse temperatures in late spring appeared to adversely modify results. In a few strains, when sufficient plants of uniform stage were not available, the means are based on less than 10 but not less than 7 replications.

For the field studies, all strains with sufficient seed (184) and Hawkeye, a standard, were planted in a randomized split-split-plot design of four replications with maturity groups (group 0 to group 4) as whole plots, treatments (check, 1/10 and 1/4 pound acid equivalent of 2,4,5-T per acre) as sub-plots and strains within treatments as sub-sub-plots. Plots were single-row 11 feet long with 36 inches between rows. Wide alleyways (5 feet) were provided between ranges. All strains within maturity groups were sprayed at the same date when the majority of the strains were at full bloom. Spray application was made across the rows about 12 to 18 inches above foliage height with a special plot sprayer, tractor mounted, at 8 gallons per acre under 40 pounds pressure. Data recorded include stage of bloom when sprayed, date ripe, and seed yield. It was necessary to hand-pick threshed seed from treated plots to remove stem pieces from brittle stalks that could not be removed by screens.

RESULTS AND DISCUSSION

Because the data reported herein are based on a large number of introductions, none of which is a named variety, the major portion of results will be presented in frequency distributions without reference to specific P.I. numbers. Detailed data on some of the most tolerant and most susceptible strains are summarized in table 4.

[1] Journal Paper No. J-2629 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 944. Received for publication Oct. 26, 1954. This manuscript is based upon work for a Federal Government Agency under contract with Iowa State College.

[2] Formerly Graduate Assistant and Professor in Charge of Farm Crops, respectively, Agronomy Dept., Iowa State College.

[3] Williams, James Henry. Crop variety response to exogenous growth regulators. I. Suppression of root growth by 2,4-dichlorophenoxyacetic acid. Iowa State College Library. 1950.

[4] Seed was obtained in 1951 through the courtesy of Dr. M. G. Weiss, then Senior Agronomist in charge of soybeans investigations, U.S.D.A.

Table 1.—Frequency distributions of relative response of soybean strains when treated with 1/10 pound per acre acid equivalent of 2,4,5-T. (Data adjusted to regression of response on maturity date).

Maturity group	Yield in percent of check													
	5	10	15	20	25	30	35	40	45	50	55	60	Total	Mean
0	—	—	1	2	1	0	1	1	—	—	—	—	6	25.6
1	1	0	1	4	4	6	8	3	1	3	2	4	37	35.3
2	—	3	11	20	24	11	9	7	9	2	1	—	97	27.9
3	—	—	1	2	8	10	6	2	3	2	3	—	37	33.0
4	—	—	1	0	2	0	1	0	0	1	1	—	6	34.9
Totals	1	3	15	28	39	27	25	13	13	8	7	4	183	30.6

Field Studies

From an agronomic point of view the difference in response of strains to field spray applications of 2,4,5-T may be of greatest interest. These results are shown as frequency distributions in table 1 .

Among the 184 strains, one was a creeping, viny type and has been omitted from the summary. Data are presented for response only at 1/10 pound per acre because a very high proportion of those treated at 1/4 pound per acre were so severely damaged that a normal distribution was not obtained. Response of selected strains at the higher concentration is shown in table 3. From the analysis of variance, made separately for each maturity group, the interactions of strains × treatments exceeded the 1% level for each group, indicating that strains did not respond alike to 2,4,5-T applications.

Although the data show the results of spray application in terms of yield reduction, the actual response also was manifest in other ways that are difficult to measure in quantitative terms. The most obvious response (see figure 1) was extreme malformation of plants within a few days after treatment. It was not possible to measure varietal differences in foliage reaction accurately. Pods failed to set from flowers in bloom when sprayed. The most obvious reason for differential response apparently was the greater ability of some strains to recover by production of new floral primordia. The main stem and branches that had developed up to the time of treatment remained twisted, greatly enlarged, and exhibited a large number of root primordia on the stems. Stems remained green in color when non-treated plants were beginning to mature (see figure 2) but were more brittle than the latter. Originally, it was hoped that the differences in maturity between the check and treated plots might serve as an additional measure of tolerance (or ability to recover) but the abnormally high temperatures with moisture deficiency in late September ripened all strains in the treated plots within a few days and thus reduced potential spread in maturity date.

As indicated above, damage to flower buds was one of the major causes of injury. All strains within a maturity group were treated on the same day; and because the original classification for maturity apparently was not accurate, there was a strong likelihood that differences in blooming might have affected varietal response. Correlations were therefore computed, within groups, between relative yield at 1/10 pound treatment and date of maturity (date ripe is highly correlated with date bloom and more accurate to record). These data, and regression coefficients are given in table 2.

All correlations were positive, indicating that the earlier strains were more severely damaged than the later maturing strains, and two exceeding the 1% level of significance. The regressions of relative response on date maturity were consistent for all groups. On the basis of these results, values for relative response were corrected to the regression values to adjust for differences in maturity among strains within groups.

Table 2.—Correlation and regression coefficients between relative yields of soybean strains when treated with 1/10 pound per acre acid equivalent of 2,4,5-T and date of maturity of the not treated check.

Maturity group	No. of strains	Correlation	Regression
Group 0	6	0.496	1.671
1	37	.284	1.837
2	97	.529**	1.363
3	37	.756**	1.395
4	6	.669	1.401

** Significant beyond the 1% level.

It was of interest to compare the relative response of the most tolerant and most susceptible strains (treated at 1/10 pound per acre) with their relative response when treated with 1/4 pound per acre. Nineteen strains from the three upper and three lower classes in table 1 were chosen for this comparison. These data are shown in the frequency distributions in table 3. Although the range in relative response of the more tolerant strains at 1/4 pound varied from 20 to 55, several were moderately tolerant to this high concentration level. Nearly all of the more susceptible strains were very severely damaged. These results further emphasize the possibility of using the more tolerant strains as parents in breeding for greater tolerance to this growth regulator. By comparison, Hawkeye, a standard widely-grown variety had a relative yield of 34.0 and 17.1 when treated with 1/10 and 1/4 pound per acre.

Because relative tolerance as reported here is determined by yields of the check as well as treated plots, it was of interest to determine possible correlation between the yields of the check and relative tolerance. Only the 97 strains in maturity group 2 were used in this calculation, because of the large number of entries and their general adaptation in maturity to the location of this test. The correlation obtained was —0.249, which, although relatively small, exceeded the 5% level of significance. Apparently there was no strong association between yielding ability and tolerance to 2,4,5-T.

Greenhouse Studies

The frequency distributions for relative leaf size of 40 strains treated by the microdroplet technique with 2,4-D is summarized in table 5. As expected, leaf size was reduced

Table 3.—Frequency distributions of relative response of 19 of the most tolerant and 19 of the most susceptible soybean strains (based on response at 1/10 pound per acre) when treated with 1/4 pound acid equivalent 2,4,5-T per acre.

Group	Yield in percent of check											
	5	10	15	20	25	30	35	40	45	50	55	Mean
Tolerant	—	—	—	2	6	4	1	4	1	0	1	31.8
Susceptible	15	3	1	—	—	—	—	—	—	—	—	5.2

FIG. 1.—Typical foliage response to 2,4,5-T within one week after application. Left center, a very susceptible strain. Right, a more tolerant strain.

more when treated at 100 ppm. than at 50 ppm. The range in response was very great and differences among strains were significant beyond the 1% level of significance from the analysis of variance made separately for each concentration. Although extreme care was used to select plants carefully at the same stage of development at time of treatment, the error variances were relatively high for this test. Because each replication consisted of only one plant, it is possible that part of this variability was due to genetic differences among plants since field and seed observations indicated that many introductions were not pure lines. More consistent evaluation also would require better temperature control following treatment than is usually possible under usual greenhouse conditions.

Of greatest interest was the relationship between response of the 40 strains when treated with 2,4-D by the microdroplet technique and field response to 2,4,5-T. As previously stated, soybean seedlings did not show a marked response when treated with 2,4,5-T using the microdroplet method. The correlations between relative yield (adjusted to regression) and relative leaf size were -0.292 at 50 ppm. and -0.356 at 100 ppm. Only the latter correlation was significant at the 5% level. The importance of these correlations is difficult to interpret. They may be due to failure of seedling foliage tissue and the entire plant to respond to treatment in a similar way, or they may be due to differential response of strains to the two growth regulators. Previous studies (3) have shown that soybean varieties respond in a similar way to 2,4-D and 2,4,5-T ($r = 0.76$) by the root tissue test but low correlations were found between response to 2,4-D and isopropyl N-phenylcarbamate (IPC).

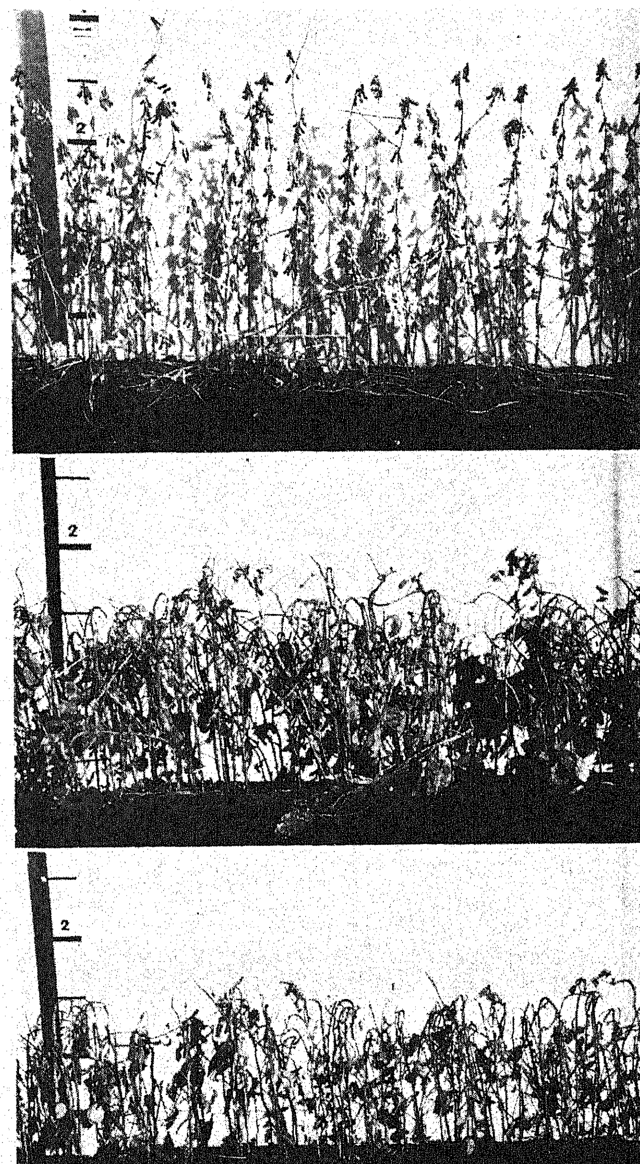

FIG. 2.—Mature plants of susceptible strain. Upper, not treated, center, treated at 1/10 pound per acre and lower, treated at 1/4 pound per acre acid equivalent of 2,4,5-T at full bloom. Note nearly complete lack of pods and short twisted stems.

The low negative correlations in the present study do suggest, however, that a screening test using 2,4-D is not an effective method for determining response to 2,4,5-T as measured by reduction in seed yield.

SUMMARY

1. A total of 183 strains of soybeans introduced from the Orient were tested to determine their response to 2,4,5-T as measured by reduction in seed yield at two rates of application, 1/10 and 1/4 pound acid equivalent per acre, in comparison with the check. Forty strains were tested for response to 2,4-D by the microdroplet technique in the greenhouse at the seedling stage of growth.

2. Highly significant differences were obtained among strains in response to 2,4,5-T. At the 1/10 pound rate about 10% of the strains showed a reduction in yield of only 40 to 50%; about 10% showed reductions of 85 to 95% in yield, and the remainder ranged between these limits. Only a few strains were tolerant at the higher concentration to the extent of yield reduction of 45 to 60%.

3. Highly significant differences also were obtained among 40 strains in response to 2,4-D applied as a microdroplet (0.013–0.014 cc.) to the first unifoliolate leaf. Reduction in leaf size of the second leaf varied from 25 to 90% with 50 ppm. and from 40 to 95% with 100 ppm. concentration.

4. Negative correlations were obtained between yield reduction of strains treated with 1/10 pound per acre of 2,4,5-T and either 50 or 100 ppm. of 2,4-D by the microdroplet method.

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Table 4.—List of more tolerant and susceptible soybean strains, including yield in bushels per acre and date of maturity of check treatment and yield in percent of check when treated with 1/10 and 1/4 pounds per acre acid equivalent of 2,4,5-T.

P.I. Numbers	Check treatment: Bu. per acre	Check treatment: Date ripe	Relative yield in % of check: 1/10 lb./A.	Relative yield in % of check: 1/4 lb./A.
		Tolerant strains		
68806	42.2	Sept. 20	50.4	43.4
70084	38.6	16	56.5	32.4
70516	40.9	16	58.0	39.4
73587	38.7	18	57.8	40.1
84681	47.2	20	53.8	38.8
87574	31.6	21	60.7	56.6
88357	40.5	16	51.4	26.9
87620	43.4	23	53.1	24.4
70218	32.2	26	53.2	27.6
70229	31.0	30	53.0	29.7
88459	37.8	28	49.0	30.2
88292	24.9	29	48.8	36.5
		Susceptible strains		
63271	34.1	Sept. 16	12.8	5.6
84810	44.6	20	14.2	4.5
68472	45.9	17	12.3	2.0
68564	44.4	17	14.2	2.0
68587	47.0	22	10.6	3.6
70559	43.6	21	11.5	4.1
79583	36.9	20	12.9	3.5
79726	48.4	17	13.2	3.1
79848	44.5	21	14.8	4.5
84637	39.8	21	14.1	2.3
Hawkeye	41.2	21	34.0	17.1

Table 5.—Frequency distributions of relative response of 40 soybean strains when treated with 50 and 100 ppm acid equivalent of 2,4-D applied with the microdroplet technique to the first trifoliolate leaf.

Concentration of 2,4-D	Leaf size of the second leaf in percent of the check: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	Mean
50 ppm.	—	1	2	4	3	4	2	5	8	5	4	1	0	0	1	38.7
100 ppm.	1	1	3	7	4	8	5	6	2	2	0	1	—	—	—	30.1

The Effect of Freezing and Thawing on Structure of the Soil Surface[1]

C. W. Domby and Helmut Kohnke[2]

THE soil surface deserves special attention in studies of soil structure. It is physically the most active zone in the soil profile, where the temperature, moisture, and air content change more widely and rapidly than at any other depth. Although most studies of soil structure are conducted during warm seasons, probably the greatest and most rapid changes in structures of the soil surface, other than those produced during tillage, result from alternate freezing and thawing of certain soils while wet. One reason that these changes in soil structure are of immediate economic concern is that they may kill crops by heaving, a process which frequently is as important as winter-killing by actual freezing of plant tissue or smothering by ice sheets.

REVIEW OF LITERATURE

Bouyoucos and McCool (2) and Taber (10, 11) discussed the mechanisms of ice crystal growth and heaving of soils, and emphasized that excessive heaving is dependent on water moving upward through the soil to the zone of freezing, and connot be accounted for by the change in volume of water upon freezing. As water in the surface layer of soil freezes, the soil moisture tension greatly increases. Therefore, a tension gradient is created, and additional water moves up from the wet soil, where water is held at low tensions, into the freezing layer where it is held at high tensions. This process may continue until the pores in the surface layer of soil are not only filled by ice, but are enlarged by the ice accumulation, expanding and heaving the soil. Much of the more recent work related to heaving of soils, primarily from an engineering viewpoint, has been brought together in a symposium on frost action in soils (4).

Four major factors influencing the amount of heaving of soils discussed in the literature (2, 4, 5, 10) are:

1.—the availability of water in the soil and subsoil; 2.—the rate at which water can be conducted through the soil to the zone of freezing, primarily as a liquid; 3.—the rate of cooling of the soil; and 4.—the amount and effectiveness of insulators at the soil surface, including snow, grass, litter, mulches, etc. Maximum heaving would occur when there is abundant water in the soil and subsoil, in soils of relatively fine texture and high capillary conductivity, such as silt loam and very fine sand, when the soil freezes slowly,and when it is bare.

Although it is generally recognized that freezing and thawing affect the structure of many soils, no simple generalization can be made concerning this effect, which seems to depend on at least the following:

1. *The moisture content of the freezing and thawing soil (6, 8).*—If the soil is not too wet, its aggregation may be improved; if a very wet soil is frozen and thawed, even previously existing aggregates may be destroyed.

2. *The rate of freezing and amount of water left unfrozen (6, 8).*—When a soil is frozen slowly, ice is segregated into large layers or crystals, with appreciable amounts of unfrozen water in the soil between the crystals. If the moisture content of the soil was not too great, a desirable crumb-like structure may result upon thawing. When a fine-textured soil is frozen rapidly, ice is uniformly distributed in small crystals through the soil; such a soil is likely to have a disaggregated structure when it thaws.

3. *Frequency of freezing and thawing (1, 9).*—Frequent freezing and thawing may be less effective in developing aggregation, or may be more destructive to aggregation, than occasional freezing and thawing.

4. *The soil texture and organic matter content (1, 8).*—Clay soils with high organic matter content seem most likely to be improved structurally by freezing and thawing; silty soils with low organic matter content seem most likely to be dispersed.

Because of the large number of possible combinations of the above factors, freezing and thawing could affect soil structure in many different ways. It is evident, however, that there is a strong similarity between those conditions which favor heaving of the soil and the conditions which lead to a breakdown of soil structure.

EXPERIMENTAL PROCEDURE

A series of small plots was estblished at the Agronomy Farm of Purdue University, near Lafayette, Ind., for studies of the structure of the soil surface. The soil was a Russell silt loam derived from glacial till, with good surface drainage and fair internal drainage. Treatments established during the summer of 1950 and continued until the summer of 1952 included bare soil, soil with two tons of oat straw per acre as a surface mulch, and soil under a straw mulch suspended on wire netting about 3 inches above the surface.

Periodic determinations were made of the bulk density and water-stability of the surface half inch and second half inch of soil. Stability of aggregation of 2 to 5 mm. fragments was determined by wet sieving using a method comparable to that of Bryant *et al.* (3), with results expressed as mean weight-diameters (12). Bulk densities and moisture contents of soil in the field, except when frozen, were determined with 13.6-ml. sampling cans about ½ inch deep.

The daily trends in moisture contents and bulk densities of the alternately freezing and thawing bare soil surface and of the underlying soil were studied during part of March, 1952. When the air temperature dropped to 20 to 25° F. at night, bare soil which had thawed during the previous day usually froze to a depth of about 1 inch. Under these conditions, the frozen soil surface in the morning had a structure and moisture content comparable to that which Post and Dreibelbis (7) described as having "concrete" structure. It was characterized by the presence of a large amount of ice uniformly distributed through the frozen soil, without large lenses, layers, or needles of ice, and with no apparent air space remaining in the frozen layer. In the mornings, blocks of the concrete-like frozen soil surface were cut out with a stiff-bladed knife in much the same way that a watermelon is "plugged". In some cases, these frozen blocks of soil were measured and their volumes calculated; in all cases, their moisture contents were determined gravimetrically. Close agreement was obtained between the bulk densities calculated from the measured dimensions and those calculated from the moisture contents, assuming that all pores were ice-filled.

In the afternoons, the bulk densities and moisture contents of the surface half inch of thawed soil were determined with the small sampling cans. Whenever samples of the soil surface were taken, moisture samples were also taken from just below the zone of daily freezing and thawing.

RESULTS AND DISCUSSION

General Effect of Winter on Structure of the Soil Surface

The greatest changes in structure of the surface of the Russell silt loam occurred during the winter. The effect of

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various treatments on the changes in water-stability of this soil are summarized in table 1. The mean weight-diameter of the water-stable aggregates in the surface half inch of the bare plots declined markedly during the first winter. The water-stability of the mulched soil declined during the second winter, presumably because partial decomposition of the mulch had reduced its effectiveness. Even during the first winter there were decreases in water-stability of the soil at a depth of ½ to 1 inch under the mulch, but the bare soil had the greatest decrease in water-stability at this depth.

Increases in density of the surface of mulched as well as of bare soils occurred during the winter. The mean bulk densities (weight of solids per volume) of mulched as well as of bare soils increased from approximately 1.15 g. per cc. in September, 1950, to 1.35 gm. per cc. the following spring, with a loss of about half the volume of pores drained at a tension of 50 cm. of water ("large pores"). Soils which were loosened by tillage during the summer of 1951 became dense again during the following winter.

Diurnal Changes in Structure of the Soil Surface Caused by Alternate Freezing and Thawing

Large diurnal changes in structure as well as moisture content of the surface of this bare silt loam occurred as a result of alternate freezing and thawing during the early spring. During the process of freezing at night, sufficient ice accumulated in the surface layer to greatly reduce its bulk density and to cause heaving of the surface. The soil just below the zone of freezing and thawing, however, was drier in the mornings when ice had accumulated in the surface than in the afternoons when the surface had thawed and slumped.

Figure 1 shows the trends in air temperature and the resulting changes in moisture content and bulk density of the surface layer of soil on three bare plots during a portion of March, 1952. The diurnal variations in moisture content of the soil below the depth of daily freezing and thawing are also shown. It must be emphasized that the great diurnal variations in bulk density of the soil in the freezing zone (figure 1) are due largely to the changes in water content, not to the expansion of water in freezing. The latter could—in a soil saturated with water—account for not more than 5% bulk density changes.

Table 1.—Effect of surface cover on water-stability of Russell silt loam near Lafayette, Ind., September, 1950, to February, 1952.

Treatment	Depth inches	Sampling Date			
		Sept., 1950	April, 1951	Sept., 1951	Feb., 1952
		Mean weight-diameter, mm.*			
Bare	0–½	1.21	0.37	0.48	0.22
	½–1	1.46	0.30	0.48	0.20
Straw on surface	0–½	1.36	1.39	1.33	0.24
	½–1	1.27	0.68	0.79	0.23
Straw 3 in. above surface	0–½	1.26	1.03	1.19	0.26
	½–1	1.25	0.46	1.07	0.25

* Means of four replications.

Actually, decreases in bulk density of the soil up to 30% resulted from the accumulation of water—in ice form. The amount of ice accumulation and degree of expansion and slumping of the soil surface consistently differed on these three plots, even without apparent differences in the soils, topography, or previous treatment, and although the plots were within 50 feet of each other. Trends in soil moisture content and structure similar to those in figure 1 could be expected whenever this soil encountered a period of daily freezing and thawing while very wet. In Indiana, these conditions are more likely to occur during the spring than during the relatively dry fall.

Mulching with straw decreased diurnal changes in structure of the soil surface, probably because freezing under mulch was not so frequent as on bare soil, and also because less water froze under the mulch. Ice formed below the mulch was not as uniformly distributed through the soil as in the bare soil, and was sometimes present only as vertical needle crystals between the soil surface and the mulch, with no ice in the soil itself.

Appreciable daily variations in structure of the soil surface probably occur only during periods of alternate freezing and thawing, but it is evident that repeated freezing and expansion of the soil surface followed by its thawing and slumping results in marked winter changes in soil structure as well as in winter-killing of crops on some soils.

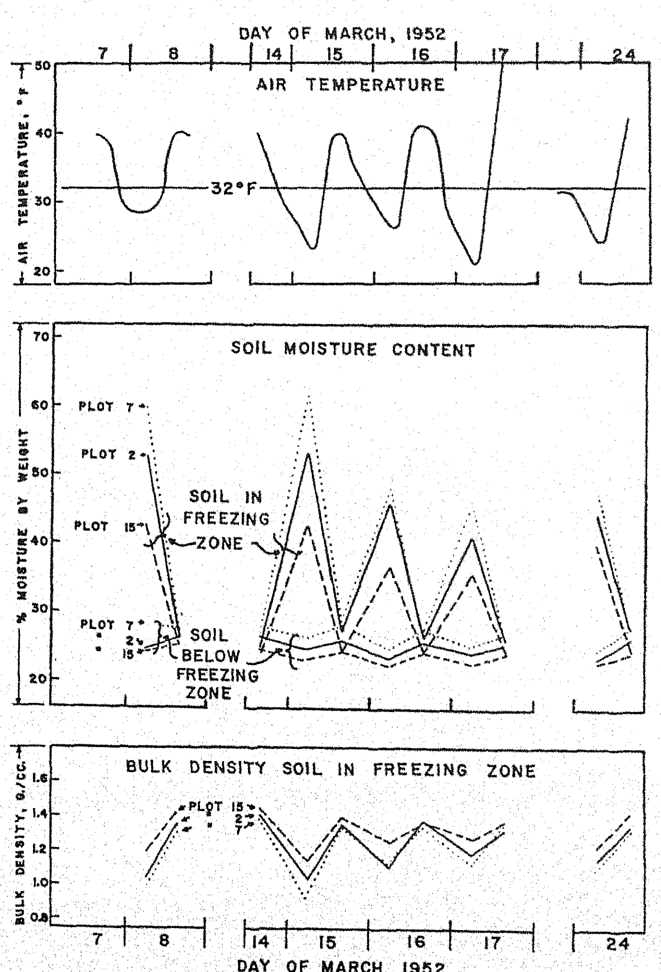

FIG. 1.—Trends in air temperature, soil moisture content, and in bulk density of the surface of three bare plots of Russell silt loam, during a portion of March 1952.

SUMMARY

Investigations of the structure of the surface inch of bare and mulched Russell silt loam were conducted near Lafayette, Ind., over a period of nearly 2 years. The greatest changes in structure of this soil occurred during the winter or early spring. The most rapid winter decrease in water-stability occurred where the soil was bare, but by the end of two winters most of the water-stable aggregates in the mulched soil also were broken down. Soil which was loose in the fall became compact during the winter, even where a surface mulch of 2 tons of straw per acre was present.

When this bare wet soil froze at night during the early spring, moisture from the underlying soil accumulated as ice in the freezing surface layer. This ice accumulation caused expansion of the soil in the frozen layer and upward heaving of the surface. When the soil thawed during the day, some of the excess moisture drained back into the soil below, and the soil surface slumped down again. The soil below the zone of daily freezing and thawing was driest when the surface was frozen, and was wettest after the surface had thawed.

Methods were described for determining the bulk densities of the frozen soil. The diurnal changes in moisture content and bulk density of the alternately freezing and thawing surface, and in the moisture content of the unfrozen soil below, during a portion of March, 1952, were shown graphically.

The similarity of the soil and weather conditions which favor heaving of the soil surface to the conditions which lead to winter breakdown of soil structure indicate a need for further investigation of the relation between soil heaving and other changes in soil structure during the winter. The need for quantitative studies of the relationship between the heaving of the soil surface and the winter-killing of crops is also suggested.

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Variability in Letoria and Fulwin Oats[1]

A. T. Wallace, G. K. Middleton, R. E. Comstock, and H. F. Robinson[2]

STUDIES by Coffman and Stanton (3); Coffman, Parker, and Quisenberry (2); and Morey (9) have shown that oat varieties differ in degree of intra-variety variability. It has been generally recognized that varieties of the species *Avena byzantina* show greater intra-varietal variability for plant and seed characters than *sativa* varieties. As a partial explanation of this, Garber and Quisenberry (6) report more natural crossing between *byzantina* varieties than between *sativa* varieties.

In heterosis studies, Coffman and Stevens (4) have shown that some varieties of oats influence the yield of F_1 progeny more than others. The variety Bond seemed to depress the yield in F_1 hybrids, whereas Markton and Victoria increased it. In some crosses, heterosis existed in kernel weight, height, panicle length, and total plant weight, whereas the culm number was usually decreased, as Coffman and Davis (1) have shown.

Hybrid progeny were frequently earlier in heading than the parents, according to Coffman and Wiebe (5). Owing to the earliness of the F_1 plants, these authors state, culms per plant and total plant weight seemed of little value as measures of hybrid vigor.

Genetic studies of quantitative characters present serious difficulties since the number of genes involved is usually large and the effect of single genes is usually small. One method of study, used in an attempt to overcome the difficulties, compares the variance of segregating and non-segregating material. Mather (8), working with oat data collected by Quisenberry, used the variance of the parents as an estimate of the environmental variance which he subtracted from the F_2 variance to get an estimate of the total genetic variance. This technique always raises the question of the genetic uniformity of the parents, since previous studies (2, 3, 9) have shown that certain oat varieties are not uniform. Poole and Grimball (10), working with watermelons, and Powers (11), working with barley, have used the variances of non-segregating material as an estimate of the environmental portion of the variances in segregating material. Powers (11) added, however, that erroneous conclusions may be drawn in estimating residual genic variability by using parental data as an absolute measure of environmental variances, since the amount of variation due to the environment is not the same for all genotypes.

This study was one of a series designed to determine if the Letoria and Fulwin oat varieties differ in genotype for the six characters, viz.: height, culm number, seed number per plant, weight of seed per plant, weight per seed, and seed number per panicle.

MATERIALS AND METHODS

Letoria, released in 1941 from the North Carolina Experiment Station, is a selection from the cross between Lee and Victoria. Lee is classified as *Avena sativa* and Victoria is classified as *Avena byzantina*. Fulwin is a selection from Fulghum, released in 1941 from the Tennessee Experiment Station, and classified as *Avena byzantina*.

Fifteen crosses involving different pairs of parent plants in the two oat varieties, Letoria and Fulwin, were made in 1947. The F_1 seeds and the selfed seeds of the 30 parent plants were maintained separately. In the fall of 1948, seed from the 15 crosses and the seed from their respective parents were space-planted 4 inches apart in rows 12 inches apart and 16 feet long in a split plot design with 4 replications. The whole plots consisted of 2 F_2 rows from each cross bordered by rows of the specific parents of the cross, on each side. The height in centimeters, culm number per plant, seed number per plant, weight of seed per plant, weight per seed in grams, and seed number per panicle were determined for each of 20 randomly selected plants in each row.

EXPERIMENTAL RESULTS

Crosses.—Mean squares in table 1 show that the variation among Letoria parents was not significant in any of the six characters. On the other hand, there were significant differences among the 15 Fulwin parents for each character except number of seed per panicle, and also significant differences between the crosses in the F_2 population for each of the characters except yield.

Heterosis.—If it is assumed that heterosis exists when the mean of the progeny is significantly greater than the average of the parents, then heterosis in the progeny of these two varieties did exist for each character, as is indicated in table 2, which gives a test of significance between the average mean of the parents and the means of the F_2's. The t-values shown in column 6 of table 2 are highly significant for each character.

Genetic Variability.—If the average of the within-row variances of the two parents is used as an estimate of the environmental contribution to the variance within the F_2 rows, then after subtraction of the within-parent variances from the within F_2 variance, an estimate of the total genetic contribution to the variance in the F_2 population is obtained.

Columns 2 and 3 in table 3 show the intra-plot variance of the parents and of the F_2's, respectively, for all 6 characters. Column 4 gives the estimated genetic variance and Column 5 the estimated genetic variance of the F_2's as a percent of the total F_2 variance.

DISCUSSION

The variability found in the Fulwin variety may stem from several possible origins. The variety may not have been homozygous at the time when it was released, or a mechanical mixture could have occurred with other varieties after it was released. There is still a possible third explanation. According to Huskins (7), there have been many reports of fatuoids (false wild oats) in the *byzantina* species. Apparently these fatuoids originate from non-homologous chromosome cross-overs. Therefore, if non-homologous chromosome cross-overs do occur and fatuoids result from such a cross-over, then it is reasonable to expect that such cross-overs could also bring about other changes. This supposition has been substantiated by Morey (9), who has investigated the morphological variability in the Clinton oat. This variability

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Table 1.—Mean squares for 6 quantitative characters among the 15 Letoria and the 15 Fulwin parents and among the 15 F_2 populations.

Character	Letoria	F_2's	Fulwin
Yield per plant in gms.	0.8057	0.9850	1.2325**
Height per plant in cms.	21.8655	113.9112**	125.0274**
Culm number per plant	3.4205	1.8247**	5.1151**
Number seed per plant	1611.0974	3657.1500**	4157.1560**
Weight per seed in centigrams	0.0271	0.0439**	0.0386*
Number seed per panicle	7.8954	54.0704**	29.3184

* Significant at 5% level.
** Significant at 1% level.

Table 2.—The mean of the parents, the average means of the parents, the means of the F_2's, and a test of significance between the average parent means and F_2 means for the character studied.

Character	Letoria	Fulwin	Mean of both parents	F_2 means	t-values
Yield per plant	2.797	2.267	2.532	3.932	9.92*
Height in cm.	65.208	84.408	74.808	79.580	7.02
Culm number/plant	10.645	5.073	7.859	8.884	6.19
Seed number/plant	133.423	139.341	136.382	198.529	8.85
Weight/seed	0.021	0.016	0.018	0.019	4.95
Seed number/panicle	12.350	26.463	19.409	22.239	3.72

* t 0.05 = 2.14
t 0.01 = 2.97

in the Fulwin variety emphasizes the fact that single plants or small samples of plants from the variety may not be representative of the variety.

The highly significant t-values in table 2 indicate that these two varieties had different genes for the characters studied, and that these genes combined in the F_2's to give an increase in vigor for these characters. A question of interest is whether those gene differences are quantitative genes as such or whether some of the extra vigor is due to disease resistant genes which were combined in the F_2's.

First of all, Letoria is resistant to crown rust, but susceptible to mosaic. Fulwin, on the other hand, is susceptible to crown rust but resistant to mosaic. The amount of rust on the susceptible parent and on the F_2 population was insignificant and no attempt was made to correlate rust readings with other characters. However, on one complete replication, the degree of mosaic infestation was determined. The plants were rated from 0 to 4, 4 being the most severe. The mean for F_2's was 1.68 and for the Letoria parents was 2.43. Correlations were computed between the mosaic ratings and each of the six characters. They are as follows:

	Letoria	F_2's
Mosaic × height	−0.203	−0.250
Mosaic × wt./seed	− .019	− .147
Mosaic × number seed/panicle	− .180	− .231
Mosaic × number seed/plant	− .014	− .097
Mosaic × yield	− .031	− .110
Mosaic × culm number/plant	.124	.109
5% r	0.113	0.088
1% r	.148	.115

Although these correlations are small they tend to indicate that as the mosaic was increased there was a corresponding decrease in expression of each character except culm number in both the Letoria and the F_2 populations. However, in spite of the depressing effect on the characters by mosaic, the F_2 progeny exhibited heterosis for each character. This expression of heterosis may be due to the fact that the F_2's were affected less by the mosaic than the average of the parents and/or that there were genetic differences between the two varieties other than disease resistance. The heterosis also indicates at least partial dominance in gene action at some of the loci where genotype of the two varieties differed.

In table 3, it would appear that the F_2's had considerable genetic variation, especially for yield and seed number per plant, which were 62.8% and 59.2% respectively of the corresponding phenotypic variance. The estimated genetic variance for number of seed/panicle was 33.2% and for height and culm number about 18%. These estimates were obtained by using the average intra-plot variances of the parents as an estimate of the F_2 environmental variance. However, upon examining table 4, which gives the intra-plot variances of both parents and for the F_2's, one may question the validity of direct comparison of variety and F_2 variances as a basis for estimating the genetic portion of the F_2 variance. It should be noted (table 4) that although yield and seed number per plant have larger intra-plot variance in the F_2's than in either parent, one of the parents has a larger intra-plot variance for each of the other four characters than does the F_2 generation.

When the means (table 1) and the variances (table 4) are compared, a strong relationship is disclosed. For example, the intra-plot variance of culm number in the Letoria parent is about 22% greater than in the F_2 population. The culm number mean is also larger (about 13%) for the Letoria parent than for the F_2 population. This relationship holds for each of the four characters that were represented by larger intra-plot variances in one of the parents. On the other hand, for yield and seed number per plant, the intra-plot variances for the F_2 population were larger than for either parent, and the means of the F_2's were also larger than either of the parents.

[3] Although this assumption may not be entirely valid, it has merit. For instance, the correlations between means and variances for yield is 0.830, and for height, 0.997. The other characters have similar relationships.

Table 3.—Average intra-plot parent variance, intra-plot F_2 variance, estimated genetic variance in F_2's, and genetic variance expressed as a percent of total F_2 variance.

Character	Intra-plot variance		Genetic variance*	Genetic variance as % of total†
	Parents	F_2's		
Yield/plant	3.456	9.313	5.857	62.88
Height	120.126	146.655	26.529	18.08
Culm number	15.757	19.358	3.601	18.60
Number seed/plant	9001.799	22065.170	13063.371	59.20
Weight per seed	0.175	0.114	0.000	0.00
Number seed/panicle	87.496	131.050	43.554	33.23

* F_2 variance minus parent variance

† $\frac{F_2 \text{ variance minus parent variance} \times 100}{F_2 \text{ variance}}$

By assuming a linear relationship[3] between means and variances the environmental variances observed in the varieties were adjusted to the F_2 means as follows:

$$\text{Adjusted Ve} = V + (M_2 - M)\frac{(V' - V)}{M' - M}$$

Where M = the smaller parent mean
M' = the greater parent mean
M_2 = the F_2 mean
V = the variance of the parent with the smaller mean
V' = the variance of the parent with the greater mean

For example, in case of height

$$Ve = 78.25 + (79.6 - 65.2)\frac{(162.00 - 78.25)}{(84.4 - 65.2)} = 141.06$$

The results from this procedure are presented in table 5.

The estimates of the genetic variances as a percent of the total variance (when parent environmental variance is adjusted to F_2 means) presented in table 5 are considerably less than those presented in table 3. No doubt the genetic variance estimates presented in table 3 are biased upward by the large means of the F_2's. The adjusted genetic variance estimates presented in table 5 may well be biased downward and, if so, are conservative estimates.

Primary interest in these estimates centers on the estimate of the genetic variance for yield. In light of the heterosis expressed for yield and the amount of genetic variance estimated (29% of the total F_2 variance), one may conclude that these two varieties differ genetically with respect to yield.

SUMMARY

The progeny from 15 crosses between Letoria and Fulwin oats were studied. The sample of Fulwin oats used in this study was found to be variable for the characters yield, height, culm number per plant, weight per seed, and seed number per plant. On the other hand, the sample of Letoria was uniform for these characters. This information indicates that material obtained from a mating between single plants from each of the two varieties may not be representative of the average for the cross of those varieties.

The F_2 exhibited heterosis in all characters studied, and for yield and seeds per plant they exceeded both parents.

Genotypic variance of all characters was estimated *(1)* by the difference between F_2 variance and the mean of the par-

Table 4.—Intra-plot variances of Letoria, Fulwin, and the F_2's and their standard deviation.

Character	Letoria	Fulwin	F_2's
Yield	4.060 ± 0.249	2.860 ± 0.261	9.310 ± 0.649
Height	78.250 ± 4.340	162.000 ± 9.420	146.650 ± 6.180
Culms	24.640 ± 1.400	6.880 ± 0.730	19.360 ± 0.900
Seed/plant	7982.530 ± 484.000	10021.070 ± 755.000	22065.170 ± 1513.000
Weight/seed	0.226 ± 0.047	0.125 ± 0.043	0.113 ± 0.026
Seed/panicle	36.190 ± 3.000	142.800 ± 12.860	131.050 ± 8.170

Table 5.—Observed F_2 variances, average variance of parents adjusted to F_2 means, estimates of F_2 genetic variances, and the latter as a percent of the total F_2 variance.

Character	Total F_2 variance	Adjusted variance (Ve)	Estimate of F_2 genetic variance	Genetic variance as % of total
Yield	9.32	6.62	2.70	29
Height	146.65	141.06	5.59	4
Culms	19.36	19.02	0.34	2
Seed/plant	22065.00	30403.00	0.00	0
Weight/seed	0.113	0.185	0.00	0
Seed/panicle	131.05	110.91	20.14	15

ent variances and (2) by the same difference but with the mean parent variance adjusted to the F_2 means assuming a linear relation between means and environmental variances. The latter estimates suggest considerable genotypic variance in the F_2 yield and seeds per panicle but little if any in the other four characters studied. However, the observation of significant heterosis in all characters leaves no doubt that the parent varieties differ in genotype for all traits and hence, that genotypic variance for all traits in the F_2 is inescapable.

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Linkage Relationships of the Martin, Hussar, Turkey, and Rio Genes For Bunt Resistance in Wheat[1]

C. W. Schaller and F. N. Briggs[2]

THE identification and cataloging of germ plasm resistant to pathogenic organisms are basic to the successful development of resistant varieties. This may be done either on a varietal or gene basis and by the use of either pure or mixed cultures of the pathogene. However, for greatest utility such an index should be reduced to its simplest component, that of gene-race interaction. With this information available, the development of resistant varieties resolves itself to the proper combination of the available germ plasm to provide for maximum race coverage. Information on the linkage relationships of the genes involved is necessary to determine whether the desired combinations can be obtained.

Briggs and associates (1, 2, 6, 11, 16)[3] have identified seven genes conditioning resistance to race T-1 of *Tilletia caries* (DC.) Tul. Two of the genes in combination provide protection against at least 25 of the 31 races presently isolated (10). Although four of these genes are located in one linkage group (9, 16),[3] sufficient crossing-over occurs to permit their combination into one variety if desired. In this paper additional information on the linkage relationships of these genes is presented. The genetics of resistance of two varieties, California 3028 and California 3029, which contribute information to some of the linkage values under consideration is also reported.

MATERIALS AND METHODS

Stanford (16) reported linkage between the R gene for bunt resistance in Rio and the T gene in Turkey 3055. However, his data did not permit a reliable estimate of the recombination value between them. Subsequently, test crosses were made to provide this information. The F_1 hybrid of Rio (*Rt*) × Turkey 3055 (*rT*) was crossed with the susceptible varieties, White Federation, Poso, and Big Club. The F_2 progenies of these crosses were tested for their reaction to bunt.

The resistant varieties, Calif. 3028 and Calif. 3029, were crossed with the susceptible variety Baart and with the resistant varieties Martin, Turkey 3055, Rio, and Selection 1403, which are testers for the M, T, R, and H genes, respectively. Although a small F_2 population of each cross was inoculated, the genetical analysis was based on F_3 progeny tests.

All of the material tested for bunt reaction was inoculated by dusting the seed with chlamydospores of race T-1 of *T. caries*. This collection has been used in all previous studies at this station. The progenies of all crosses, except with the tester varieties Martin, Turkey 3055, Rio, and Selection 1403, were grown in duplicate rod rows. Only single progeny rows of the test crosses were grown. Eighty seeds were planted in each row. Resistant and susceptible parental checks were included at regular intervals. The plants were pulled when nearly mature and classified as diseased or healthy.

Calif. 3028 and Calif. 3029 are selections of Turkey wheat obtained from W. J. Sando, Agronomist, United States Department of Agriculture. They have been highly resistant to race T-1 over an 11-year period with only one infected plant having been found in each variety.

The genetics of the resistance in Rio and Turkey 3055 wheats have been reported previously by Stanford (16) and Briggs (6), respectively.

RESULTS

Crosses Between (Turkey 3055 × Rio) F_1 and White Federation, Poso, and Big Club

These crosses were designed to measure the frequency of parental and recombination gametes produced by the F_1 hybrid of the cross Turkey 3055 (*Tr*) × Rio (*tR*). If crossing-over occurred, four types of zygotes would be expected in crosses with susceptible varieties having the recessive allele at each locus, i.e. *Trtr*, *tRtr*, *TRtr*, and *trtr*. The frequency of these types would provide an estimate of the recombination value between the T and R genes.

[1] Contribution from the Department of Agronomy, University of California, Davis, Calif. Rec. for publication Nov. 2, 1954.

[2] Assistant Professor and Professor of Agronomy, respectively.

[3] E. P. Baker. Inheritance of resistance to bunt (*Tilletia caries* (DC.) Tul.) in hybrids involving Turkey wheat selections 10095 and 10097. Ph.D. thesis, University of California, Berkeley, Calif., 1949.

Briggs (6) and Stanford (16) have shown that the average infection in progenies segregating only for the T gene or the R gene is 40.0 and 45.0%, respectively. Although no information is available on the amount of bunt to be expected in progenies segregating for the T and R genes in the coupling phase, it should be less than for those in which the genes occur alone. Progenies from the double recessive combination would be fully susceptible.

Six hundred thirty-four F_2 progenies from the cross (Turkey 3055 × Rio) F_1 × White Federation and 76 F_2 progenies with Poso as the susceptible parent were tested for smut reaction in 1948. Unfortunately, the level of infection was extremely low, with an average of 42.1 and 41.5% bunt in the White Federation and Poso checks. The distribution curve of the F_2 progenies showed no clear cut minima which could be interpreted as distinguishing genotypic classes. Consequently, no attempt was made to estimate linkage from these data.

All of the lines in which the infection was 65% or more of the two adjacent check plots in 1948 were retested in 1949. The distribution of parental plots and F_2 progenies by 5% infection classes is given in table 1. The range of infection in White Federation was from 65.1 to 87.3% with an average of 78.3%.

A definite minimum in the distribution curve occurred at the 55 to 65% infection level, which approximated the lower range of the parental plots (table 1). If this minimum in the curve is accepted as the separation point between the heterozygous and susceptible families, 51 families would then be classified as susceptible. The average infection of these lines was 74.4%, which was in close agreement with the value of 78.3% for the susceptible checks. The 1949 results were correlated with those obtained in 1948 to determine whether any of the susceptible progenies might have been missed by not retesting the entire population. None of the 25 lines rested whose infection was between 65 to 70% of the adjacent checks in 1948 was found to be susceptible in 1949. This was considered sufficient evidence that all of the lines in which the infection was less than 65% of the adjacent checks in 1948 were heterozygous and not susceptible.

The distributional pattern of the lines with less than 60% infection in 1949 showed no clear cut minima which could be used to separate the three other genotypes expected in progenies of this cross. The 51 susceptible lines represented 8.16% of the total F_2 population of 625 families and is a measure of the frequency of the recombination gamete *tr* produced by the F_1 hybrid. The recombination value between the T and R genes, as calculated from these data, was 16.32 ± 1.46%.

Similar interpretation of the data (table 1) from the cross with Poso as the susceptible parent gave a recombination value of 18.42 ± 4.44%.

Four hundred twenty-three F_2 progenies of the cross (Turkey 3055 × Rio) F_1 × Big Club were tested for their reaction to bunt in 1954. The distributions of the parental plots and F_2 progenies by 5% infection classes are given in table 1. The range of infection in Big Club, the susceptible variety, was from 71.8 to 98.9% with an average of 90.8%. A definite minimum in the distribution curve was evident at the 75 to 85% infection level. This was accentuated by the prominent declension in the curve from the 62.5% class to the 77.5% class. The mid-point of this minimum, 80.0% infection, was considered to be the point of separation between the segregating and susceptible families. This was in agreement with the minimum obtained by Stanford (16) with comparable levels of infection. Although some of the susceptible progenies might be expected to have less than 80% infection as suggested by the distribution of the parental rows, it is believed that they would be offset by the presence of segregating rows with more than 80.0% infection. The exact proportion of each type within the minimal classes could be determined only by additional tests. The significant shift in the point of separation of the segregating and susceptible progenies between the tests in 1949 and 1954 can be accounted for by the higher level of infection resulting from environmental conditions extremely favorable for bunt development in 1954. This is evident when comparing the distribution of the parental checks as well as the average infection for the 2 years (table 1).

Twenty-eight progenies, or 6.6% of the total population, had more than 80.0% infection and were considered to be homozygous susceptible. The average infection of these lines was 86.8% which is in close agreement with the value of 90.2% for the susceptible check rows. The recombination value between the T and R genes calculated from these data was 13.24 ± 1.65%.

The estimate of linkage from the combined data provided by the 3 crosses was 15.18 ± 1.57%. The non-significant χ^2 value in the tests for homogeneity (χ^2 = 1.0639 with 2 d.f., P = 0.7 – 0.5) indicated that the three sets of data were in agreement in supporting this value.

Crosses Involving Calif. 3028 and Calif. 3029

The distributions by 5% classes for bunt infection of the parental checks and the F_3 progenies of the various crosses involving Calif. 3028 and Calif. 3029 are presented in table 1. Both varieties were highly resistant with an average infection of 0.02% and 0.03% for Calif. 3028 and Calif. 3029, respectively. The range of infection in Baart, the susceptible variety, was from 42.5 to 92.5% with an average infection of 67.3%.

The distribution curves of the F_3 progenies of the crosses with Baart appear to be divided into three parts by definite minima at the 7.5 and 37.5% classes (table 1). The minimum at the 37.5% class coincided with the lower range of the Baart plots; consequently, all of the progenies with more than 37.5% infection were considered to be susceptible. The minimum at the 7.5% class appeared to separate the resistant and the heterozygous progenies. Since overlapping of the two types would be expected in the minimal class, half the progenies in the 7.5% class were arbitrarily assigned to each type. In the Calif. 3028 cross there were 48 resistant, 87 heterozygous, and 62 susceptible F_3 progenies. This suggested a 1:2:1 ratio which would be expected with monofactorial segregation. In the cross Calif. 3029 × Baart there were 60 resistant, 158 heterozygous and 60 susceptible progenies which also suggested a ratio of 1:2:1. Chi square tests for goodness of fit of observed to expected ratios gave P values of 0.2 – 0.1 and 0.1 – 0.05 for Calif. 3028 and Calif. 3029, respectively. The average infection of 16.7% and 16.8% in the heterozygous rows indicated dominance of expression. Consequently, the resistance of each variety can be ascribed to a single dominant gene pair.

No segregation occurred in crosses with the variety Martin, which is the tester variety for the M gene. In the cross with Calif. 3028 no susceptible plants were found among 408 F_2 plants or in 161 F_3 progeny rows involving 7374 plants. Likewise, none was found in a population of 306 F_2 plants and in 148 F_3 progeny rows in the cross with Calif. 3029.

The absence of segregation indicated that the resistance of these two varieties was conditioned by the M gene or by one closely linked with it. In a population of 148 F_3 progenies, one segregating row would have been expected ($P = 0.95$) with a recombination value of 2.0% or greater. Since the distributional pattern of the F_3 progenies in the crosses with the susceptible variety Baart was the same as that obtained by Briggs and other (1, 3, 4, 15) with crosses involving the M gene, it can be assumed that this gene is present in the two varieties.

Susceptible F_3 progenies occurred in all crosses with Turkey 3055, Rio, and Sel. 1403 which are tester varieties for the T, R, and H genes, respectively. In analyzing these crosses for linkage relationships, those progenies within the range of the susceptible Baart checks were considered susceptible. However, in some cases, there appeared to be some overlapping of the heterozygous and susceptible rows. This might be expected since the mean infection in the rows segregating for the tester genes may approach 40 to 50% under favorable conditions.

The observed number of resistant and segregating:susceptible F_3 progenies in the hybrids with Turkey 3055 agreed with the 15:1 ratio expected with independent segregation (table 2). In the hybrid Calif. 3029 × Turkey 3055 the distribution agreed equally well with the ratio expected for linkage between the M and T genes with a recombination value of 34.22% as reported by Briggs (9). However, in the Calif. 3029 cross there was an excessive number of susceptible progenies. From an examination of the distribution of these progenies (table 1), it was noted that 15 of the 21 progenies classified as susceptible, or 71.4%, fell within the 42.5 to 52.5% infection classes, whereas only 11.8% of the susceptible checks were within this range. Since these classes are within the infection range of the progenies heterozygous for the T gene, misclassification could account for the high number of susceptible progenies obtained.

Stanford (16) reported linkage between the R and M genes with 28.1 ± 6.16% recombination. The cross-over value obtained in the cross Calif. 3028 × Rio was found to be 27.6 ± 6.16%. Although the segregation obtained in the hybrid between Calif. 30.29 × Rio agreed with that expected with independent segregation ($P = 0.20 - 0.10$), there were only nine susceptible progeny when 15 were expected. The combined estimate of linkage from the data of the two crosses was 33.5 ± 6.14% which was within one standard error of the value obtained by Stanford.

Linkage between the M and H genes was suggested in the crosses with Sel. 1403. There were 3 susceptible progenies in the cross with Calif. 3028 and 4 in the cross with Calif. 3029, when 10 were expected in each cross. The deviation from the expected 15:1 ratio was significant with Calif. 3028 ($P = 0.05 - 0.02$) and approached significance with Calif. 3029 ($P = 0.10 - 0.05$). When the data from the two crosses were combined, the deviation was highly significant ($P = < 0.01$). The deficiency in these crosses of rows segregating for the H gene supports the evidence of linkage. Briggs (2) found the mean infection of rows heterozygous for the H gene was 44.2% with a range from 22.5

Table 1.—Distribution of parents, F_2 and F_3 progenies of the crosses named into 5% classes for bunt infection.

	Number of rows or progenies in 5% infection classes																					
	0–5		5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100	Total
	0	0.1–5																				
White Federation	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2	7	2	1	–	–	13
(Turkey 3055 × Rio)F₁ × White Fed.	–	–	–	–	3	11	15	22	18	21	13	9	3	4	13	12	16	4	2	–	–	166*
Poso	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	1	–	–	–	3
(Turkey 3055 × Rio)F₁ × Poso	–	–	–	–	–	–	5	9	2	4	0	2	0	1	1	3	1	1	–	–	–	29†
Big Club	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	2	4	6	8	3	—
(Turkey 3055 × Rio)F₁ × Big Club	–	–	1	4	5	13	21	20	25	32	60	58	42	48	30	26	9	9	14	5	–	423
Calif. 3028	26	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	27
Calif. 3029	24	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	25
Martin	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10
Sel. 1403	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
Turkey 3055	8	5	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16
Rio	7	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15
Baart	–	–	–	–	–	–	–	–	–	1	5	5	10	10	20	17	10	11	1	2	–	92
Calif. 3028 × Baart	36	8	8	34	37	8	3	1	1	4	5	9	9	12	7	7	6	1	1	–	–	197
Calif. 3029 × Baart	46	10	9	51	65	31	4	2	0	2	5	6	13	10	8	7	6	2	1	–	–	278
Calif. 3028 × Martin	161	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	161
Calif. 3029 × Martin	148	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	148
Calif. 3028 × Turkey 3055	92	45	44	25	24	10	6	6	7	5	6	4	0	2	1	1	1	1	–	–	–	280
Calif. 3029 × Turkey 3055	88	62	40	15	11	9	3	6	4	0	1	6	2	2	1	0	0	0	–	–	–	250
Calif. 3028 × Rio	131	63	28	16	8	7	2	2	0	3	1	1	0	0	–	–	–	–	–	–	–	262
Calif. 3029 × Rio	99	47	41	23	11	8	4	3	1	2	3	2	1	1	–	–	–	–	–	–	–	246
Calif. 3028 × Sel. 1403	86	30	20	6	6	4	1	2	0	1	0	0	0	0	1	0	1	–	–	–	–	158
Calif. 3029 × Sel. 1403	89	27	12	8	4	4	1	1	1	1	1	0	1	1	0	0	0	–	–	–	–	151

* Total population = 634 lines tested in 1948; only those lines with an average infection of more than 65% of the susceptible checks were retested in 1949.
† Total population = 76 lines; see footnote above.

to 62.5%. In the two crosses under discussion there were only 21 F_3 progenies in a total population of 309 that had more than 20.0% infection and which could be considered either heterozygous for the H gene or homozygous susceptible (table 1). With independent segregation 3/16 of the total population or 58 F_3 progeny should be of these genotypes. This deviation was highly significant ($P = < 0.01$). Since considerable overlapping of progenies heterozygous either for the M gene or the H gene might be expected within the infection range of 15 to 30%, the estimation of linkage was based only on the identification of the susceptible progenies. A recombination value of 30.75 ± 5.63% was obtained from the pooled data. The inclusion of the H gene in the MXRT linkage group places five of the seven genes for bunt resistance on one chromosome.

DISCUSSION

The results of numerous investigations involving the linkage relationships of the genes conditioning resistance to race T-1 of *Tilletia caries* in wheat have been published by Briggs and associates (9, 15, 16).[4] Linkage between the M and T (9, 15), M and R (15, 16), and T and R (16) genes has been established. Heretofore, the H gene was considered to be independent of the others. In view of the evidence presented in this paper which suggested an association between the M and H genes, it appeared desirable to summarize all of the data available in respect to linkage relationships between the various genes.

Briggs (2) and Smeltzer (15) reported independence of the M and H genes. However, their data showed a deficiency in the number of susceptible progeny observed in relation to the number expected with a 15:1 ratio. Likewise, an examination of the distribution of F_3 families obtained by them revealed a deficiency of progenies heterozygous for the H gene which would suggest linkage. Four sets of data involving crosses between the M and H genes were available for study. These data are summarized in table 2. In each of the

[4] Baker, *Ibid.*

Table 2.—The ratios of resistant and heterozygous to susceptible progenies in crosses involving resistance to bunt, and goodness of fit to ratios indicated

Hybrid	Literature citation	No. of F_3 progenies observed: Resistant and heterozygous	Susceptible	Ratio: Res. and Het.: Susceptible	Probability: 15:1 ratio	With recombination value as indicated
MM × HH						(37.24 ± 4.19%)
Calif. 3028 × Sel. 1403	——	155	3	52:1	>0.02	>0.20
Calif. 3029 × Sel. 1403	——	147	4	32:1	>0.05	>0.50
Sel. 1418 × Martin	(2)	78	3	26:1	>0.20	>0.90
Cooperatorka × Sel. 1403	(15)	146	9	16:1	>0.70	>0.10
Total		526	19	28:1	<0.01	
MM × RR						(29.25 ± 3.09%)
Calif. 3028 × Rio	——	257	5	51:1	<0.01	>0.80
Calif. 3029 × Rio	——	237	9	27:1	>0.10	>0.05
Rio × Martin	(16)	249	5	50:1	<0.01	>0.80
Cooperatorka × Rio	(15)	259	3	86:1	<0.01	>0.20
Total		1022	22	46:1	<0.01	
MM × TT						(39.71 ± 2.45%)
Calif. 3028	——	259	21	12:1	>0.30	<0.01
Calif. 3029	——	238	12	20:1	>0.30	>0.30
Martin × Turkey 3055	(5)	183	7	26:1	>0.10	>0.90
Martin × Turkey 1558	(5)	179	4	45:1	>0.03	>0.20
Sherman × Turkey 3055	(7)	136	4	34:1	>0.05	>0.50
Martin × Oro	(7)	101	3	34:1	>0.10	>0.50
Martin × Turkey 1558B	(8)	114	7	29:1	>0.20	>0.70
Martin × Turkey 2578	(8)	116	3	39:1	>0.10	>0.30
Cooperatorka × Turkey 3055	(15)	211	5	42:1	>0.02	>0.20
Total		1534	63	24:1	<0.01	
RR × HH						
Rio × Sel. 1403	(16)	238	12	20:1	>0.30	
HH × TT						
Sel. 1403 × Turkey 3055	(6)	127	11	12:1	>0.50	
		F_2 Progenies				
TtRr × ttrr		(Heterozygous)	(Susceptible)		3:1 ratio	(15.18 ± 1.57%)
(Turkey 3055 × Rio) F_1 × White Federation		581	51	12:1	<0.01	>0.50
(Turkey 3055 × Rio) F_1 × Poso		69	7	10:1	<0.01	>0.50
(Turkey 3055 × Rio) F_1 × Big Club		394	28	14:1	<0.01	>0.30
Total		1047	86	12:1	<0.01	

four F_3 populations the ratio of resistant heterozygous to susceptible progenies exceeded the 15:1 ratio expected with independence (table 2). Although the deviation from the expected ratio was significant in only one case, the deviations were all in the same direction and the χ^2 value for the pooled data was highly significant (P = < 0.01). When the four populations were tested for homogeneity, according to the method of Snedecor and Brandt, described by Fisher (12) the χ^2 value was nonsignificant (P = 0.5 – 0.3). Thus the four sets agree in indicating a deficiency of susceptible progeny for a good fit to the 15:1 ratio expected with independence. The recombination value estimated from the combined data by the method of maximum likelihood was 37.24 ± 4.19%. The P values for the individual crosses are given in table 2.

Four sets of data were available for estimating the cross-over value between the M and R genes. These are given in table 2. The ratio of resistant and segregating to susceptible progenies exceed the 15:1 ratio in all cases. The deviations for 3 of the 4 crosses and for the total were highly significant (P = <0.01). The cross-over value calculated from the combined data was 29.25 ± 3.09%. The nonsignificant χ^2 value for heterogeneity (P = 0.5 – 0.3) indicated that the 4 populations agreed in supporting the recombination value obtained.

Briggs (9) in 1940 summarized the results of six crosses involving linkage between the M and T genes. A recombination value of 34.22% was obtained. Three additional sets of data are now available for use in calculating the intensity of this linkage. The data for the nine crosses are summarized in table 2. The ratio of resistant and heterozygous to susceptible progenies exceeded the 15:1 ratio in all but 1 of the 9 populations. In the cross Calif. 3028 × Turkey 3055 the ratio obtained was less than a 15:1, indicating an excess of susceptible progenies. However, as was pointed out previously in this paper, this discrepancy could be readily accounted for by misclassification.

When the data from the 9 crosses were considered together, there were only 63 susceptible progenies when 100 were expected. This deviation was highly significant (P = < 0.01). A recombination value of 39.71 ± 2.45% was calculated from the combined data. Eight of the nine populations were in good agreement in supporting this value (table 2). The ratio obtained in the cross Calif. 3028 × Turkey 3055 differed significantly (P = < 0.01) from that expected with linkage and accounted for more than two-thirds of the heterogeneity χ^2 value (χ^2 = 14.21, with 8 d.f., P = 0.10 – 0.05). The apparent failure to separate accurately the heterozygous and susceptible progenies in this cross would account for the excessive number of susceptible progenies. When this population was omitted from the calculations, a recombination value of 35.85 ± 2.72% was obtained. Because of the discrepancy noted above, this latter value should be a better estimate of the true relationship between the M and T genes.

Only one set of data was available for each of the crosses involving H × R and H × T. Independence of these combinations was indicated (table 2). Thus, the following order of the four genes is suggested:

|←————39.7 ± 2.4%————→|
|←—37.2 ± 4.2%—→|←–29.3 ± 3.1%–→|15.2 ± 1.6%|
H M R T

Baker[5] found the X gene to be linked with M, R, and T. Since independence was suggested between H and X, it can be assumed that the X gene is located beyond the M gene in respect to the H gene. No additional information is available on this linkage.

Five of the seven genes conditioning resistance to race T-1 of *Tilletia caries* have been shown to be associated in one linkage group. This non-random distribution of the resistance genes between the linkage groups of a species is comparable with the results obtained with powdery mildew of barley (14) and rust of flax (13). Although only three of the five linked genes have been found in a single variety, the amount of crossing-over between them will permit their combination into a single variety with little difficulty.

SUMMARY

Evidence is presented which establishes linkage between the Hussar and Martin genes for bunt resistance, with a recombination value of 37.2 ± 4.2%. Heretofore, the H gene was considered to be independent of the MXRT complex. Thus, five of the seven genes positively identified which condition resistance to race T-1 of *Tilletia caries* are in one linkage group.

All of the data available on the linkage relationships of these genes was summarized. The arrangement of the genes within the linkage group was presented. The recombination value of 15.2 ± 1.6% between the R and T genes obtained from test crosses involving three susceptible varieties differed significantly from the value of 2.4% previously reported (16).

The resistance of Calif. 3028 and Calif. 3029 was found to be conditioned by the Martin gene. This gene has now been identified in nine varieties.

[5] *Ibid.*

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Comparison of Actual and Predicted Gains in Barley Selection Experiments[1]

K. J. Frey and T. Horner[2]

SINCE Fisher[3] first proposed the idea of partitioning variances, numerous experiments have been conducted by animal and plant breeders to determine the relative importance of environmental and genetic variances in heterogeneous populations. The ratio of genotypic to total variance was termed "heritability" by Lush[4]. It is possible to find in the literature, heritability percentages for various characteristics in most of the important crop plants. However, the literature is notably void of reports testing the realism of heritability values.

The study reported herein was conducted to test the accuracy of heritability percentages for four characters in barley by comparing predicted gains with those actually obtained in selection experiments. The barley plant characteristics measured, namely, yield, test weight, heading date, and plant height, were each considered to be multigenically inherited.

MATERIALS AND METHODS

The data reported herein were collected from barley yield tests grown at East Lansing, Mich., in 1951 and 1952. Fifty-one random lines from the cross, Stewart $\times$ Bay, and 39 lines randomly selected from those which were stem rust resistant in the cross, Kindred $\times$ Bay, were grown in a yield test in the F_4 generation in 1951 and the F_5 in 1952. Each F_4 and F_5 barley line was composed of the bulk population derived from a single F_2 plant. Each plot was 1 row 8 feet long, and the field design was a randomized block with 4 replications.

Two methods used for calculating heritability were: *(1)*, the regression of the performance of F_5 barley lines on the corresponding F_4 lines, and *(2)*, the ratio of genotypic variance of genotypic plus environmental variances obtained from a components of variance analysis of the F_4 experiment.

The formula used in calculating heritability by this method was:

$$\hat{H} = \frac{\hat{\sigma}^2_s}{\hat{\sigma}^2_s + \hat{\sigma}^2_e/r},$$

where $\hat{H}$ equaled the estimated heritability, $\hat{\sigma}^2_s$ and $\hat{\sigma}^2_e$ were the estimates of between line variance and environmental variance, respectively, and r is the number of replications. It can be shown,[5] under the assumptions of normal diploid behavior at meiosis, no multiple alleles, no linkage, no epistasis, and no genotype environmental interactions, that σ^2_s is equal to the sum of the additive genetic variance plus 1/16 of the dominance variance, while the covariance of mean performance of F_2 lines of the F_4 and F_5 generations is equal to the sum of the additive genetic variance plus 1/32 of the dominance variance. This dominance causes

$$H = \frac{\sigma^2_s}{\sigma^2_s + \sigma^2_e/r},$$

to have a slight upward bias.

For each characteristic studied, between 10% and 12% of the F_4 population representing the most superior lines in each barley cross were hypothetically selected as parental stock to propagate the F_5. The predicted mean performance (predicted gain) of the F_5 progenies derived from selected F_4 lines was obtained by multiplying the performance differential between the F_4 population and parental sample means by the heritability percentage. The predicted gain was then compared with the actual mean performance differential between the progeny of the selected parents and the F_5 population mean. If the calculated heritability percentages were reliable and realistic, the predicted and actual gains in performance would approximate one another. This method of comparison was used on each measured characteristic in both crosses except for yield in the Kindred $\times$ Bay cross. Since the magnitude of yield, test weight, and plant height were not at the same level for the 2 years, it was necessary to express the expected and actual gain as a percentage of the F_4 and F_5 population means, respectively.

RESULTS

The heritability percentages for yield, test weight, heading date, and plant height in the two barley crosses as calculated by the parent-progeny regression and variance components methods are presented in table 1. Heading date was the only characteristic which showed good agreement between the two methods of calculating heritability. For yield in the Stewart $\times$ Bay cross, bushel weight in the Kindred $\times$ Bay cross, and plant height in both crosses, the estimate of herit-

[1] Journal Paper No. J-2640 of the Iowa Agr. Exp. Sta., Ames, Iowa. Project No. 1177. Rec. for publication Nov. 17, 1954. Joint contribution from the departments of Agronomy and Statistics.

[2] Associate Professor of Farm Crops and Assistant Professor of Statistics, respectively.

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Table 1.—Heritability percentages for yield, test weight, date of heading, and plant height in two barley crosses calculated by parent-progeny regression and components of variance methods.

Characteristic	Cross	Method of calculation	
		Regression	Components of variance
Yield	Stewart × Bay	39	59
Test weight	Stewart × Bay	96	78
	Kindred × Bay	53	60
Plant height	Stewart × Bay	42	75
	Kindred × Bay	50	68
Date of heading	Stewart × Bay	93	94
	Kindred × Bay	85	83

ability by the regression method was lower than by the components of variance method, and for the test weight in the Stewart × Bay cross the converse was true.

The heritability percentages given in table 1 follow the general pattern of those obtained in other studies, namely, date of heading has a high heritability while test weight, yield and height are more easily influenced by environment and, therefore, have lower heritabilities.

It is noteworthy that the heritability percentages calculated by the components of variance method were larger in each case in the Stewart × Bay cross than their counterparts in the Kindred × Bay cross. This was probably caused by the fact that the range for each characteristic was greater in the first cross than in the latter.

The actual versus predicted gains obtained with selection are given in tables 2, 3, 4, and 5 for yield, test weight, plant height, and heading date, respectively. The heritability percentages used in preparing these tables were obtained from the components of variance column in table 1. The selected parental sample in the F_4 of the Stewart × Bay cross yielded 13.0% higher than the population mean, while mean yield of their progenies was 12.1% of the F_5 population mean showing close agreement between the predicted and actual gains in yield through selection. There was good agreement between the expected and actual gains for test weight in the Kindred × Bay cross being 2.0 and 1.7%, respectively, of the population means. In the Stewart × Bay cross the discrepancy between expected and actual gains in bushel weight was quite large being 3.9 and 6.7%, respectively, of the mean.

For plant height, actual gains when expressed as percentage of the population mean fit the expected gains very well in both crosses. In fact, in the Kindred × Bay cross they were almost identical, 4.8 and 4.9% for actual and expected gains, respectively, while in the Stewart × Bay cross they were 8.4 and 7.6%, respectively. The expected gain in heading date in the Kindred × Bay cross was almost identical to that actually obtained. However, in the Stewart × Bay cross the selected sample progenies averaged only 2.9 days earlier than the population mean, while it was expected that they would be 3.4 days earlier. When taller or later parental samples were selected from the F_4 populations the actual gain obtained in their progenies agreed as closely to the gain predicted as the examples shown in tables 4 and 5, so the selection of the earliest and shortest strains as parents herein does not bias the results.

Table 2.—Predicted vs. actual gain in yield by selection in the Stewart × Bay barley cross.

Item	Generation	
	F_4 (1951) gms.	F_5 (1952) gms.
Population mean	88.5	118.9
Selected sample mean*	108.0	133.3
Difference (D)	19.5	14.4
Predicted gain (H × D)	11.5	——
Actual gain	——	14.4
Gain as % of population mean	13.0	12.1

* 5 high yielding lines selected.

Table 3.—Predicted vs. actual gain in test weight with selection in two barley crosses.

Item	Cross			
	Stewart × Bay		Kindred × Bay	
	F_4 (gms./25cc.)	F_5 (gms./25cc.)	F_4 (gms./25cc.)	F_5 (gms./25cc.)
Population mean	33.8	29.7	34.3	30.4
Selected sample mean	35.5*	31.7	35.5†	30.9
Difference (D)	1.7	2.0	1.2	0.5
Predicted gain (H × D)	1.3	——	0.7	——
Actual gain	——	2.0	——	0.5
Gain as % of population mean	3.9	6.7	2.0	1.7

* 7 high bushel weight lines selected.
† 6 high bushel weight lines selected.

Table 4.—Predicted vs. actual gain in plant height with selection in two barley crosses.

Item	Cross			
	Stewart × Bay		Kindred × Bay	
	F_4 (ins.)	F_5 (ins.)	F_4 (ins.)	F_5 (ins.)
Population mean	29.8	26.3	32.9	29.1
Selected sample mean	26.5*	24.3	30.6†	27.7
Difference (D)	3.3	2.0	2.3	1.4
Predicted gain (H × D)	2.5	——	1.6	——
Actual gain	——	2.0	——	1.4
Gain as % of population mean	8.4	7.6	4.9	4.8

* 4 shortest lines selected.
† 5 shortest lines selected.

The usefulness of heritability percentages depends upon their reliability which in turn can be proved only in practice. Probably plant breeders will agree that in practice selected phenotypic gain is more nearly maintained in characteristics with high heritability percentages than those with low. However, the data reported herein for barley are even more encouraging because not only do the between-character comparisons fall into line with expectation from experience, but the within-character gains obtained by selection are very close to those predicted. The only extremely divergent case

was for test weight in the Stewart × Bay cross where the actual gain was nearly twice that expected.

DISCUSSION

The three most common methods for calculating heritability percentages are parent-progeny regressions and two variance components procedures, one where the environmental variance is estimated from error deviations in a replicated trial, and the other where the variance within an isogenic line is considered to be an estimate of environmental variance. The latter variance components method usually used to measure heritability in the F_2 of a segregating cross leads to estimates in the broad sense.[6] However, the other two procedures give estimates of heritability in the narrow sense. In other words they tend to be based largely on the additive genetic effects which are truly heritable. Therefore, it would be expected that heritability percentages calculated from the same data by these two methods should be quite similar. Any discrepancy between the two methods should be as noted earlier in a higher estimation by the components of variance method due to the greater effect of dominance. The upward bias in the F_4 and F_5 should be only slight. This postulated upward bias might account for the fact (tables 2 to 5) that except for test weight in the Stewart × Bay cross and heading date in the Kindred × Bay cross, the expected gains were slightly but consistently greater than those actually obtained.

As pointed out earlier, there was close agreement between the two methods in only two of the seven comparisons. In both crosses there was good agreement for date of heading, while in four of the five other cases, namely, yield in the Stewart × Bay cross, test weight in the Kindred × Bay cross, and plant height in both crosses, the regression method gave lower heritability percentages than the variance components method. These differences were too great in magnitude to be accounted for by dominance effects, especially since the variance components method was more accurate in these four cases as evidenced by the fact that the actual gain obtained coincided more closely with those predicted by this method than those predicted by the regression method. Only for test weight in the Stewart × Bay cross was the converse true, and in this case neither method gave a very close approximation between expected and actual gains.

The most realistic method of calculating heritabilities would seem to be by parent-offspring regression since it more nearly represents what plant breeders practice when selecting within segregating populations. It incorporates genotype-environment interactions which are inherent with practice but are not so prominent in heritability percentages calculated from one set of environmental conditions.

Heritability percentages calculated by the components of variance method are usually based on data from one generation and year and then are applied to the next generation. Under such circumstances, a great deal of discrepancy would be expected between the gain obtained in the F_5 and that predicted on the basis of the F_4 because of genotype-year interaction. However, contrary to this theory the components of variance method overall gave heritability percentages which most closely fit the results obtained in these selection experiments. Apparently, the regression method tended to underestimate the true heritability percentages. Of course, an

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Table 5.—Predicted vs. actual gain in heading date with selection in two barley crosses.

Item	Cross			
	Stewart × Bay		Kindred × Bay	
	F_4 (days)	F_5 (days)	F_4 (days)	F_5 (days)
Population mean	10.5*	8.4	12.2	10.2
Selected sample mean	6.8†	5.5	8.5‡	7.0
Difference (D)	3.7	2.9	3.7	3.2
Predicted gain (H × D)	3.4	——	3.1	——
Actual gain	——	2.9	——	3.2

* Days after June 12.
† 6 earliest lines selected.
‡ 5 earliest lines selected.

underestimation of heritability percentage would not be as serious as an overestimation since the actual gain obtained would be greater than that expected.

It is generally accepted that segregating populations with the widest ranges tend to give the highest heritability percentages. Such was the case herein where the heritability percentages from the Stewart × Bay cross were greater than their counterparts in the Kindred × Bay cross. This suggests the need for adjusting the heritability percentage used in calculating expected gain in performance through selection to the range of the segregating population being subjected to selection. A possible method of alleviating the effect of range on heritability percentage would be to base heritability and selection in terms of standard deviation units. This would bring all frequency distributions of performance more or less to a common base.

Insofar as the data reported herein are representative, they show the following: (a) heritability values as calculated by the components of variance method, in the F_4 and F_5 generations, are realistic and reliable; (b) the close agreement between the expected and actual gains in performance in six of the seven comparisons suggest that the gene action involved in the F_4 and F_5 generations is largely additive; (c) of the two methods of calculating heritability percentages, namely parent-progeny regression and components of variance, the latter gives closer agreement between predicted and actual gains in selection experiments; (d) the parent-progeny regression method tends to underestimate the true heritability percentages.

SUMMARY

In a comparison between two methods of calculating heritability percentages using performance data from the F_4 and F_5 of two barley crosses, the parent-progeny regression method tended to underestimate the true heritability percentages while the components of variance method gave values which closely approximated the results obtained in selection experiments. Only for date of heading was there close agreement between the heritability percentages calculated by the two methods. Other characteristics measured were yield, test weight, and plant height.

When the actual gains obtained through selection and those expected from the components of variance analysis were expressed as a percent of the population mean, the agreement was nearly perfect in all cases except test weight in the Stewart × Bay cross. In this case, the gain obtained was nearly twice as great as expected.

Expression of the "Kys" Type of Male Sterility in Strains of Corn With Normal Cytoplasm[1]

Earl R. Leng and L. F. Bauman[2]

CYTOPLASMIC male sterility has been successfully and extensively used during the past several years to reduce the amount of detasseling necessary in the production of commercial hybrid corn. However, the sterility produced by the widely-used cytoplasmic factors described by Jones (2), Jones and Mangelsdorf (3), and Rogers and Edwardson (5) normally persists into the double-cross hybrid grown in the farmer's field. Complete elimination of detasseling by the use of these sources of male sterility will not be possible until dependable fertility-restoring factors can be incorporated into inbred lines used on the pollinator side of the pedigree in commercial seed production.

As pointed out by Bauman (1) and Jugenheimer (4), the "Kys" type of male sterility, first described by Schwartz (6), appeared to offer the great advantage that fertility in the commercial double-cross hybrid could be restored automatically by using normal, standard inbred lines or their single-cross hybrids as pollinators in making up the hybrid. Breeding plans were developed (1) to introduce this source of sterility into several inbred lines commonly used on the seed parent side of commercial hybrids, and the source material was widely distributed to station and commercial corn breeders for incorporation into their own material.

Successful utilization of the "Kys" type of sterility was dependent on the assumed presence of both cytoplasmic and genetic factors controlling the expression of sterility or fertility. Schwartz (6) had postulated that sterility would result only when the proper genetic factors were combined with a specific "sterile" cytoplasm. Results obtained by the authors in the 1954–55 Florida winter nursery crop clearly indicate either that the postulated "sterile" cytoplasm exists in all three of the standard inbred lines tested, or else that no cytoplasmic factor is involved. In either case, it appears on present evidence that this source of sterility *cannot* be used to produce a fully sterile plant population.

It is the purpose of this paper to give a brief outline of the breeding procedures employed and the results obtained, as well as to present the evidence for the absence of a "fertile" cytoplasm in the inbred lines studied. It is also the desire of the authors to emphasize that, on the basis of present knowledge, this source of sterility cannot be employed successfully in the production of commercial corn hybrids.

GENETIC THEORY AND BREEDING PROGRAM

Schwartz (6) described the occurrence of the "Kys" type of male sterility as resulting from the interaction of a specific "sterile" cytoplasm with two pairs of genetic factors. According to this explanation, sterility would occur only in plants which carried the "sterile" cytoplasm, were at least heterozygous for the dominant male-sterility gene Ms_{21}, and were homozygous for the recessive "suppressor" gene $s^{ga}s^{ga}$. On this basis, all alternative conditions either of the cytoplasm or of the genetic factors would produce complete fertility (table 1).

Extensive tests conducted by the junior author (1) indicated that all of 250 inbred lines tested were homozygous for the dominant suppressor allele $S^{GA}S^{GA}$. Breeding tests with four standard inbred lines indicated that they carried the homozygous dominant factors $Ms_{21}Ms_{21}$, and it was considered that inbred Kys probably was unique in carrying the recessive alleles of both genes. Tests of the cytoplasmic constitution of the standard lines were not conducted, since such tests would have required several plant generations, and since there was no apparent reason to question the existence of a specific "sterile" cytoplasm, as postulated by Schwartz.

Essentially, the complex breeding procedure finally developed (table 2) involved the identification of double recessive individuals, carrying the "sterile" cytoplasm, with progressively higher proportions of the recurrent inbred germ plasm. These were then used as female parents in backcrosses to the recurrent line, to retain the "sterile" cytoplasm, and the resulting progeny were again crossed to the recovered $ms_{21}ms_{21}$ $s^{ga}s^{ga}$ stock. Finally, when "sterile cytoplasm, double

Table 1—Expression of the "Kys" type of male sterility in corn, as influenced by cytoplasm and genotype, according to hypothesis of Schwartz (6).

Assumed cytoplasmic condition	Genotype*	Abbreviated symbols†	Phenotype
"Sterile"	$Ms_{21}Ms_{21}$ $s^{ga}s^{ga}$	□ $MsMs$ ss	Sterile
"Fertile"	$Ms_{21}Ms_{21}$ $s^{ga}s^{ga}$	O $MsMs$ ss	Fertile
"Sterile"	$ms_{21}ms_{21}$ $s^{ga}s^{ga}$	□ $msms$ ss	Fertile
"Sterile"	$Ms_{21}Ms_{21}$ $S^{GA}S^{GA}$	□ $MsMs$ SS	Fertile
"Sterile"	$ms_{21}ms_{21}$ $S^{GA}S^{GA}$	□ $msms$ SS	Fertile
"Fertile"	any other	O - - - - -	Fertile

* Heterozygous condition, $Ms_{21}ms_{21}$, would produce same phenotype as homozygous dominant.

† □ = "sterile" cytoplasm $Ms = Ms_{21}$ $S = S^{GA}$

O = "fertile" cytoplasm $ms = ms_{21}$ $s = s^{ga}$

Table 2.—Planned breeding procedure for incorporation of "Kys" type of male sterility into inbred lines of corn.

Generation	Female parent	×	Male parent
1	□ $msms$ ss (Kys M.S.)	×	O $MsMs$ SS (WF9)
2	□ $Msms$ Ss	×	□ $msms$ ss (Kys M.S.)
3	□ $msms$ ss (25% WF9) (selected segregate)	×	O $MsMs$ SS (WF9)
4	□ $Msms$ Ss (62.5% WF9)	×	□ $msms$ ss (25% WF9)

(Repeat cycles until approximately 95% increment of inbred germ plasm reached)

[1] Contribution from the Department of Agronomy, Illinois Agr. Exp. Sta., Urbana, Ill. Published with the approval of the Director of the Illinois Agr. Exp. Sta. Received for publication March 15, 1955.

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Table 3.—Proposed utilization of the "Kys" type of male sterility in the production of commercial hybrid corn.*

Generation	Female parent	Male parent
Foundation single cross	□ *msms ss* (fertile) recovered WF9	× O *MsMs ss* (fertile) recovered 38–11
Double-cross production	□ *Msms ss* (male sterile) recovered WF9 × rec. 38–11	× O *MsMs SS* (fertile) normal Hy × L317
Farmer's crop	□ *MsMs SS* □ *Msms SS* □ *MsMs Ss* □ *Msms Ss* } (all fertile) recovered U. S. 13	

* Dependent on the presence of specific "sterile" and "fertile" cytoplasms, as indicated.

Table 4.—Segregation of male sterile and fertile plants in progenies with assumed "sterile" and "fertile" cytoplasms. Data from observations at Homestead, Florida, February, 1955.

Recurrent inbred line	"Sterile cytoplasm" crosses (□ *Msms Ss* × *msms ss*)			"Fertile cytoplasm" crosses (O *Msms Ss* × □ *msms ss*)		
	Number of families	Sterile plants	Fertile plants	Number of families	Sterile plants	Fertile plants
38–11	8	78	199	6	52	141
WF9	2	23	47	3	28	70
Hy2	5	36	108	6	49	144
Totals	15	137	354	15	129	355

recessive" stocks with a sufficiently high proportion of the recurrent line's germ plasm had been produced, they were to be used to produce a "fertile cytoplasm, $Ms_{21}Ms_{21}$ $s^{ga}s^{ga}$" type[3]. According to Schwartz' hypothesis, such types should have been *genotypically* male sterile, but *phenotypically* male fertile, because of the presence of the "fertile" cytoplasm. Fully male-sterile single cross hybrids were then to be produced from two male fertile recovered lines by the procedure outlined in table 3.

CRITICAL TESTS AND RESULTS

After several generations of experimental breeding, employing the four widely-used standard inbred lines WF9, 38–11, Hy2, and M14, the first cross of the type

O *MsMs SS* × □ *msms ss*[4]
(normal inbred 38–11) (tester)

was made by the junior author in 1953. The backcross to the tester

O *Msms Ss* × □ *msms ss*

was made in the 1953–54 Florida winter nursery, and the resulting segregating population was grown by the senior author in 1954. Severe drouth prevented pollen shedding in most of the plants, and no satisfactory observations were made.

Additional crosses of this type, involving the three normal inbreds WF9, 38–11, and Hy2 and various recovered □ *msms ss* stocks, were made in the 1953–54 Florida nursery. The backcrosses to the respective □ *msms ss* stocks were made at Urbana in 1954. When the resulting segregating progenies were grown in the 1954–55 Florida winter nursery, it was found (table 4) that they were segregating for male sterility in exactly the manner which would have been expected had they been carrying "sterile" cytoplasm.

Comparison of the ratios of sterile to fertile plants in these progenies, carrying the presumed "fertile" cytoplasm, with those of similar progenies carrying "sterile" cytoplasm showed (table 4) that the two sets of ratios were virtually identical. It was therefore concluded that inbreds WF9, 38–11, and Hy2 were carrying a "sterile" cytoplasm also, or else that no specific "sterile" cytoplasm actually was necessary for the expression of the "Kys" type of male sterility.

DISCUSSION

The feasibility of using the "Kys" type of male sterility in commercial seed production was dependent on the development and use of a cytoplasmically *fertile*, genotypically *sterile* recovered inbred line, which would actually be male fertile. Therefore, it is obvious that this system cannot be used with inbred lines which do not carry a "fertile" cytoplasm. The three lines tested in the studies reported here all proved to carry a "sterile" cytoplasm, or its equivalent. Obviously, then, this source of male sterility cannot be used successfully with these lines. Further, these findings raise considerable doubt that any specific "sterile" cytoplasm actually is necessary for the expression of male sterility in plants of the "sterile" genotype $Ms_{21}ms_{21}$ $s^{ga}s^{ga}$.

It is not the purpose of this paper to give a detailed analysis of this and other anomalies in the obviously complex inheritance of the "Kys" type of male sterility in corn. Although extensive data are available, further test crosses and counts of segregating populations will be required to clarify the situation. On the basis of present evidence, however, the authors emphasize that there appears to be no justification for further attempts to incorporate this source of sterility into inbred lines for use in commercial production.

[3] Bauman, L. F. Results of further inheritance studies on the Kys type of cytoplasmic male sterility in corn. Paper presented at the 1953 meetings of the American Society of Agronomy, Dallas, Tex., November 16–20, 1953.

[4] Refer to table 1 for key to abbreviated notation.

SUMMARY

The "Kys" type of male sterility in corn has been described as resulting from the interaction of a specific "sterile" cytoplasm with two pairs of genetic factors, namely, a dominant male sterility gene, Ms_{21}, and a recessive suppressor gene pair, $s^{ga}s^{ga}$. This type of male sterility appeared to offer definite advantages over other types now being used to eliminate detasseling in the production of hybrid seed corn, and a breeding program was begun at the Illinois Station to incorporate the assumed "sterile" cytoplasm and the necessary genetic factors into four widely-used standard inbred lines.

Successful utilization of the "Kys" type of sterility depended on the ultimate production of one or more recovered lines which would be *genotypically* sterile, but *phenotypically* fertile, because of the presence of "fertile" cytoplasm. Attempts to produce such stocks revealed that all three inbred lines tested carried a "sterile", rather than a "fertile" cytoplasm; in fact, the data obtained raised the definite possibility that no special condition of the cytoplasm is necessary for the production of the "Kys" type of sterility.

These results indicate that this type of male sterility cannot be employed successfully to produce fully male-sterile single crosses, for use in hybrid seed corn production. It is therefore recommended that efforts to incorporate the "Kys" type of sterility into inbred lines for such use be discontinued.

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Pros and Cons of Changing Fertilizer Guarantees from the Oxide to the Elemental Basis[1] [2]

THE fertilizer industry throughout the world is undergoing a tremendous expansion and more changes in technology than ever before in its history. It has long ago ceased to be a by-products or waste-products business and has become a major segment of the heavy chemical industry.

For at least 30 years there has been some agitation to discontinue the practice of expressing the phosphorus and potassium contents of fertilizers in terms of the oxides. However, it appears that little effort has been made to describe the history of this practice or to record the pertinent discussions concerning the advisability of making a change. The problem has received more attention in some of the European countries than in the United States.

The current discussion in this country originated with a resolution which was passed by the Middle West agronomists at a joint agronomy-industry meeting sponsored by the Middle West Soil Improvement Committee, Feb. 16, 1951. The resolution read as follows:

"This resolution is directed to a number of organizations, including the following:

- Middle West Soil Improvement Committee
- National Fertilizer Association
- American Plant Food Council
- Southern Agricultural Workers Association
- Association of Official Agricultural Chemists
- Fertilizer Division of the American Chemical Society
- National Soil & Fertilizer Research Committee
- The American Horticultural Society
- American Society of Agronomy, and
- Soil Science Society of America

"Agronomists of the North Central Region, at the time of their annual meeting on Feb. 15, 1951, to consider fertilizer grades, ratios, and other matters pertaining to fertilizer usage, recommended to the above-named group that consideration be given to the matter of expressing the contents of nutrient elements in fertilizer, including the minor elements, on an elemental basis. It is hoped that the appropriate committees and/or organizations as such will discuss this matter at their next annual meetings and make such recommendations as they may deem desirable through the Secretary of the Association of Official Agricultural Chemists."

Then, the American Association of Fertilizer Control Officials in October 1952, passed the following resolution:

"Moved that the Uniform Fertilizer Bill be modified to change the designations 'phosphoric acid' to 'phosphorus' and 'potash' to 'potassium', provided, however, that permissive guarantees for P_2O_5 and K_2O may be included until such time as essentially complete conversion to the elemental basis can be effected.

"Moved further that a committee of Association of Fertilizer Control Officials be appointed to meet with representatives of the National Soil and Fertilizer Research Committee, and with committees of the Soil Science Society of America, American Plant Food Council, and National Fertilizer Association to prepare a plan for changing the method of expressing fertilizer guarantees from phosphoric acid to phosphorus, potash to potassium, and available phosphorus to soluble phosphorus."

Also, in 1952, a Sub-committee of the Fertilizer Committee of the Soil Science Society of America was appointed on "Consideration of the Advisability of Changing Fertilizer Guarantees to Elemental Basis."

This committee met with the AAFCO committee and with representatives of the fertilizer industry in Washington, D. C. in October 1953, to explore the possibilities of getting an objective analysis of the problem. It was agreed that the history of the use of these terms should be recorded and the arguments for and against a change to the elemental basis should be fully publicized as a basis for determining whether concerted action by the interested groups would be advisable.

The following statement sets forth the history of the use of these terms and the arguments which have been advanced for and against the expression of plant nutrient content of fertilizers in terms of the elements.

Historical

The use of the oxide form for reporting the composition of fertilizers, plants, and soils appears to be a carryover from rock

[1] Prepared by a Sub-committee of the Fertilizer Committee of the Soil Science Society of America on "Consideration of the Advisability of Changing Fertilizer Guarantees to the Elemental Basis". The Fertilizer Committee voted unanimously at a meeting in St. Paul, Minn., Nov. 9, 1954, to recommend that all fertilizer guarantees be expressed in terms of the element. The Executive Committee of the Soil Science Society of America approved the report of the Fertilizer Committee.

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analysis. In the latter case the oxide mode was used to show the known valences of the elements in the sample and with suitable corrections would total 100% for a complete analysis. It is difficult to determine with accuracy the exact origin of the practice of expressing the mineral content of fertilizers in the form of oxides.

Crowther (2) stated "The persistence of the old terms [P_2O_5 and K_2O] is partly due to the mistaken idea that there is something remotely academic in talking about chemical elements, partly to the desire to make analyses look bigger, but mainly to the traditional survival in agricultural and industrial chemistry of the nomenclature of a century ago." In discussing the origin of the term, P_2O_5, Smith (9) noted "Nomenclature in the textbooks of a century ago was inclined to be irregular, some authors using the terms phosphorus pentoxide or phosphoric anhydride for P_2O_5 and phosphoric acid for H_3PO_4, while others used phosphoric acid for both P_2O_5 and H_3PO_4 and sometimes hydrate of phosphoric acid for H_3PO_4. It should be remembered that the oxygen theory of acids was still prevalent about 100 years ago. In the course of time, however, the practice of calling P_2O_5 phosphoric acid seems to have become universal and agricultural chemists have rather shamefully accepted or condoned the custom."

At the Second National Fertilizer Conference held in West Baden, Ind., in 1928 the question of changing from P_2O_5 to P and from K_2O to K as a basis for expressing the phosphorus and potassium content of fertilizers was presented. The conference proceedings (7) recorded the discussion which indicated that the participants believed that there was no sound basis for using the oxide form other than the fact that state laws required it.

Sauchelli (8) in 1948 reported on a survey of the fertilizer industry on the question "N-P-K or N-P_2O_5-K_2O?" Mixed reactions to the proposal were obtained. He concluded that the use of P_2O_5 and K_2O to show the phosphorus and potassium contents of fertilizers was "a holdover from the old oxide theory which was discredited long ago." Likewise, Crowther (3) attributed the use of the oxide form to the abandoned theory that salts are compounds of "acid oxides" and "basic oxides." More recently Jacob (4) quoted a report from Denmark as follows, "It has been disappointing that the large countries still use P_2O_5 and K_2O. There is no scientific reason to do so. Why not, to be consistent, use N_2O_5 instead of N? Ammonium nitrate will then turn out to be a very concentrated fertilizer, containing more than 100 percent N_2O_5." Others have suggested that N_2O_5 would be the proper oxide form for anionic nitrogen but not for cationic nitrogen.

Sauchelli (8) pointed out that nitrogen in fertilizer was formerly expressed as ammonia, NH_3, and that the chemist using the Kjeldahl method for determining nitrogen was actually distilling NH_3 and reporting it as such. Brand (1), former executive secretary-treasurer of the National Fertilizer Association, recognized the fallacy of using the NH_3 form to express the nitrogen content of fertilizers inasmuch as some carriers do not contain ammoniacal nitrogen. In spite of all the arguments advanced against the practice of expressing nitrogen as ammonia, only since 1950 have the guarantees of nitrogen in fertilizer been expressed in terms of the element (N) in *all* the states and territories. South Carolina was the last state to make the change from NH_3 to N—Aug. 1, 1939—and complete uniformity was achieved when the change was made in Puerto Rico, Jan. 1, 1951.

Confusion of Terminology

The literature contains many confusing statements as a result of failure to adopt a uniform method of expressing the nutrient content of fertilizers, soils, and plants. The lack of consistency among writers is well known. Often, a particular writer is inconsistent, even within a sentence or paragraph. The following quotations, extracted from soils and fertilizer publications illustrate the difficulties encountered due to present terminology (italics by the authors of this report are for emphasis).

1. "A release rate for *phosphoric acid* ranging from 8 lbs. to 29 lbs. per acre per year was found at 11 different locations in a recent . . . study of *phosphorus* availability."
2. "The *phosphorus content* of the surface foot of soil varies considerably. . . . It ranges up to the equivalent of about 0.3 per cent P_2O_5 . . ."
3. "In the phosphate rock industry, the *P_2O_5 content* is usually expressed in terms of its *tricalcium phosphate*, $Ca_3(PO_4)_2$, equivalent . . ."
4. "The custom in the fertilizer trade is to express the *phosphorus* content of any type of phosphatic material as the *anhydride of phosphoric acid*, P_2O_5. This term is commonly *abbreviated*, though somewhat confusingly, to '*phosphoric acid*'."
5. "Domestic rock used in superphosphate manufacture runs 68 to 78 per cent *B.P.L. (bone phosphate of lime)* or 31 to 36 per cent of P_2O_5."
6. "Mono-calcium phosphate is synthesized by applying *phosphoric acid* to high grade phosphate rock. It contains approximately 50 per cent *available phosphoric acid*."
7. "Since the term '*potash*' covers all natural *potassium* compounds, prices are based on the hypothetical *K_2O* content of the material involved."
8. "Fertilizers supply more *SO_3* and nearly as much *CaO* as all three of the *primary nutrients*."
9. "Since nitrogen percentage is based on the elemental content whereas *phosphate* and *potash* are reported as the oxides, it can be shown that elemental fertilizer nitrogen is actually lower in cost per pound than either of its companions, *phosphorus* and *potassium*."

Objections to the Change

1. *Historical use* of the oxide form would necessitate an intensive educational effort to acquaint the farmer, industry, control officials, and agricultural workers with the new basis. A change to the elemental basis would require the use of conversion factors to data heretofore published in terms of the oxides. This would, no doubt, lead to some confusion and to additional calculations until the new system is generally accepted. For instance, the following conversion factors would need widespread publicity:

From	To	Factor
P_2O_5	P	0.44
P	P_2O_5	2.29
K_2O	K	0.83
K	K_2O	1.20

The change in ratio and grade numbers will present a "mind block", at first thought, to those accustomed to use the N-P_2O_5-K_2O system. For example, a 1:1:1 ratio will become a 7:3:6 ratio. However, such grades could be standardized readily to fit a 2:1:2 ratio on the N:P:K basis.

2. *Fertilizer laws* would need revision on a coordinated national basis. Legislative action probably would be required in many states to permit the change. In this case it would take a period of several years to accomplish the transition. It is generally agreed that during the transition period, the laws or regulations governing the sale of fertilizers should permit—and perhaps require—the phosphorus and potassium contents to be shown in terms of the oxides as well as in terms of P and K. Since the objective would be to drop eventually the oxide terms, these values should be carried as supplementary statistics in small print during the period of transition.

For the change to be made with a minimum of confusion and without penalties to those members of industry who are willing to pioneer in the field, nearly unanimous backing of all groups would be needed.

Jacob (4) noted that no particular trouble was encountered in Norway in making the change from P_2O_5 and K_2O to P and K. It is recognized, however, that a similar change in the United States would involve more complications since most of the fertilizers are sold and applied in European countries as separate materials and not as mixtures.

3. *An impression of lowering the "plant food" content* of fertilizers would be created in the minds of those without an elementary knowledge of chemistry. Since 1 part of P_2O_5 is equivalent to only 0.44 parts of P and 1 part of K_2O to 0.83 parts K, this would give to some people the impression of less "plant food" per dollar invested. By the same process, they would conclude that there was more filler in the fertilizer bag.

On the other hand, the task of educating those who are receptive would be greatly simplified. It would appear much easier to explain why superphosphate contains 8.8% phosphorus which has the symbol P than it would explain why the phosphorus content of superphosphate is shown as 20% P_2O_5 which is called

"phosphoric acid" but isn't phosphoric acid at all but is in reality phosphorus pentoxide.

4. *Costs* incidental to the change would be passed on to the farmer. Although the costs of making the change would be temporary, and ultimately savings inherent in the new system should offset them, the task of acquainting industrial personnel with the new system, mistakes which inevitably will be made in the calculation of formulas, and new plates for printing of bags and tags are items of expense which will be encountered.

5. *Whole number concepts for N, P, and K* would no doubt be retained, and as a result the change would require a complete revision of formulas for fertilizer mixtures. Until new whole number ratios could be established, decimal numbers in guarantees might be necessary in some cases while the transition is being completed in all states.

Fractions would still be involved in expressing the percentages of the minor elements in fertilizers.

Advantages of the N-P-K System

1. *Uniformity* of terminology in expressing the plant nutrient content of soils, plant materials, and fertilizers would greatly lessen the confusion in both written and spoken word. The composition of plant materials is generally expressed in present-day literature in terms of the element. This method of expression for the mineral elements is already firmly established in the animal nutrition and biochemical fields. Feeding standards for such elements as phosphorus and calcium are usually expressed in terms of the element and then converted to show the amount of a standard source material to use to supply the required level of the element in question. Likewise, soil tests are frequently calibrated on an elemental basis. A common basis for expressing the plant nutrient content of these materials would make the interpretation of soils and crop data in terms of fertilizer much simpler. Since nitrogen in fertilizers is already expressed in terms of the element, the shift would, first of all, provide for uniformity in fertilizer grade terminology.

The increasing importance of the so-called secondary and minor elements would be an additional argument for using a simple elemental basis for expressing the nutrient content of fertilizers. It is difficult to rationalize the complexity of terminology which is developing in the fertilizer field. Some nutrients are guaranteed in terms of the element, some as oxides, and some as compounds or commercial products. For example, a popular grade of fertilizer in Virginia which is recommended for alfalfa might be guaranteed to contain 2% nitrogen (N), 12% phosphoric acid (P_2O_5), 12% potash (K_2O) and 5% borax equivalent. Actually the boron may not be in the form of borax (sodium tetraborate decahydrate) at all but in the form of Colemanite (calcium borate)—a compound greatly different in solubility. Likewise the phosphorus might not be supplied in the form of orthophosphates but as calcium metaphosphate and the potassium would probably be supplied as the chloride salt of that element.

2. *Simplicity* is another worthy objective of the change. A true nomenclature of plant nutrient elements would not permit the use of such terms as "P_2O_5 or phosphoric acid" and "K_2O or potash." The increasing use of orthophosphoric acid, H_3PO_4, as a fertilizer material for direct application has added to the confusion when P_2O_5 is referred to as "Phosphoric acid." The AAFCO went on record in 1954 as favoring the abandonment of the term "phosphoric acid" for P_2O_5, recommending that it be called phosphorus pentoxide. It would be much simpler to express phosphorus as the element, and usually the simplest way is the best way. The expression of the potassium content of potassium chloride, KCl, as an oxide appears less defensible since it has been known since 1810 that there is no oxygen in KCl.

It has been pointed out that the present practice of using P_2O_5 and K_2O to express the content of phosphorus and potassium is irrational since it requires 7 symbols and figures when 2 will serve. The saving in printing, stamping, and typing—the small suffix figures require special attention by typists and printers—would be significant to say nothing of the space saved in explaining the meaning of P_2O_5 and K_2O. It is a common practice to refer to NPK fertilizers and then make calculations in terms of N, P_2O_5, and K_2O. There is little doubt that the use of such arbitrary terminology has affected materially the types and amounts of fertilizer used and has been a real obstacle in educational programs with the farmer. Progress in any field is hampered by holding to terminology and concepts long after they have been discredited.

3. *Accuracy* in stating the true ratios of the major nutrient elements in a particular fertilizer would require that they be stated in terms of the element. Expressing the nutrient content of fertilizers in such terms as P_2O_5, K_2O, CaO, SO_3, creates erroneous impressions as to the actual amounts of the plant nutrient elements in fertilizer materials. Ratios of the nutrient element contents of a fertilizer are frequently used in referring to "nutrient balance" in relation to fertilizer use. The 1:1:1 ratio denotes a favorable balance of the three elements to many people and the impression is held that because of the widespread use of fertilizers with a 1:2:1 or 1:3:1 ratio (N-P_2O_5-K_2O basis) large quantities of phosphorus in relation to the other elements are being used. Conversion to the elemental basis shows this to be a misconception, since a 1:2:1 ratio in conventional terms becomes a 1:0.88:0.83 ratio as N-P-K.

The use of the term P_2O_5 has been defended on the basis that it denotes the orthophosphate form of phosphorus in fertilizers. This is untenable since it has been shown by Jacob and Hill (5) that about 41 compounds have been identified in fertilizers and related materials. These include 23 orthophosphates, 7 pyrophosphates, 7 metaphosphates, and 4 polyphosphates.

If the oxide form originated in rock analysis as a method of showing true valence of the element, its present use in fertilizer analyses is erroneous. For example, the phosphorus content of phosphites is expressed as P_2O_5 whereas the correct oxide to show the valence of phosphorus in phosphites would be P_2O_3.

The oxide is not the basic functional unit either from a physical or chemical standpoint. The atom might be considered the functional unit from the viewpoint of the physicist but the ion would generally be the functional unit from a chemical or crystal structure point of view. Actually chemistry is of little help or importance in this case. The important information in a guarantee is the amount of the constituent and the simplest form of statement is preferable. More complex forms such as the oxide or ions convey no pertinent information. The nutritive value or "availability" of the constituent cannot be shown by the mode of expression.

Summary

Some of the valid objections to changing from the oxide to the elemental basis as a mode of expressing nutrient guarantees of fertilizers include: *(1)* Historical use of the oxide terms would require an intensive educational effort to acquaint all groups involved with the new system, *(2)* Fertilizer laws would need revision on a coordinated national scale, *(3)* Costs incidental to the change and *(4)* a complete revision of grades and formulas would be required to maintain the whole number system.

The utility of the elemental basis (the N-P-K system) in fertilizer guarantees highlights the true advantages of this system. A uniform method for stating the nutrient composition of fertilizer materials, plants, and feeds would greatly simplify exchange of information in the closely related fields of soil chemistry, fertilizer technology, and plant (and animal) nutrition. Simplicity of the elemental system and the fact that it is a more accurate expression of the plant nutrient content are strong arguments for making the change. The logic is apparent of any change which simplifies, adds consistency or uniformity, increases the accuracy, and greatly improves the usefulness of the system.

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Notes

A PORTABLE SELF-PROPELLED PLOT COMBINE[1]

THREE methods of harvesting experimental plots of small grains and seed crops have been generally employed. The method in longest use is that of cutting the plants from definite lengths of rows or numbers of quadrats by hand, bagging or wrapping them to prevent shattering and loss of seed during transportation, and threshing with a small stationary plot thresher or other means. A second method is similar except that cutting is done with a small plot mower, having some type of catcher to collect the plants as they are cut. A third method is that of employing a commercial self-propelled combine to cut and thresh the crop simultaneously.

Each of these methods has disadvantages. The relatively large amount of hand labor involved in the first two methods limits the number of plots that may be handled by an experimenter and encourages reduction in plot and sample size. Combines have the advantage of completing the harvest in a single operation. However, present day commercial self-propelled combines are of such size (7-foot cut, or larger) that the experimental area required for plots to be harvested by them may be so large as to include undesirable site heterogeneity. Relatively large amounts of labor and materials are necessary for application of treatments to plots of the required size. The machines are difficult or impractical to clean between plots of different treatments or varieties. The sample removed from the combine at the end of a plot may be contaminated by significant amounts of seed from previously harvested plots of different treatments, and is usually not suitable as a sample for chemical analyses, baking trials, or determination of other than yield effects of treatments. Because of their weight, bulk, low road speed, and the difficulties involved in transporting them by truck under bridges and overpasses, power lines, telephone lines, and other obstructions along the highways, use of commercial self-propelled combines is usually limited to sites near their permanent location.

A self-propelled plot combine was described in 1951 by Liljedahl, Hancock, and Butler.[2] Their machine was a significant advance in plot-harvesting equipment for crops that may be combined. An Allis-Chalmers Model G tractor, with front end and rear wheels removed, was mounted above the combine body as source of motive power for the truck wheels upon which the front end of the machine was carried. A 6 hp. air-cooled engine powered the thresher.

Three portable self-propelled plot combines have been constructed and used at the Oregon Agricultural Experiment Station during the 1953 and 1954 seasons. The basic unit of these machines is an Allis-Chalmers Model 40 All-Crop Harvester, stripped of frame, wheels, clean grain elevator, and tailings elevator and streamlined inside essentially as recommended by Liljedahl, Hancock, and Butler.

The combine body is placed upon a frame supported at the front by an automobile rear axle and wheels (6.00 x 16 tires) and at the rear by an automobile front axle. Each axle is shortened by 12 inches. A 9 hp. Wisconsin air-cooled engine, mounted low on the left side of the machine, supplies motive power to the automobile rear axle through two automobile transmissions. The arrangement of these components is shown in figure 1. The combine has 6 forward speeds, ranging from about 1 to 7 miles per hour. There are 3 reverse speeds. A 9 hp. Wisconsin engine, mounted low and well forward on the right side of the machine, as shown in figure 2, operates the combine. Low mounting of the engines on opposite sides of the machine results in low over-all height, low center-of-gravity, and good stability. Driver's seat and combine and engine controls are mounted on a platform supported above the machine. A hand-operated hydraulic header lift is provided. Threshed seed is collected beneath the machine in a sliding bin, which has a funnel mouth for ease in transferring to bags. An air compressor may be mounted on the platform and powered from the thresher engine, if it desired to thoroughly clean the machine between varieties.

The complete machine weighs approximately 3,000 pounds. It may easily be driven onto a tilting bed implement trailer under its own power. Loaded thus, it will pass under obstacles

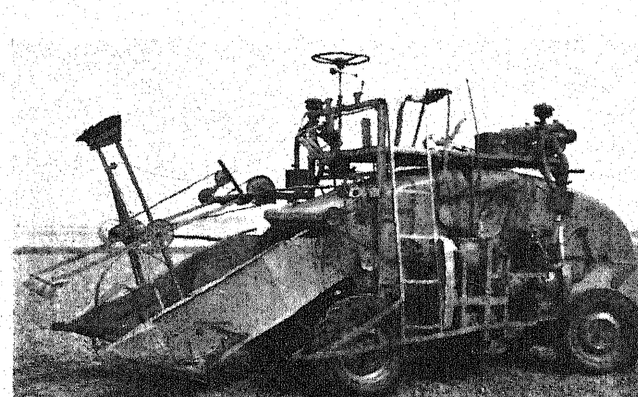


FIG. 1.—Propulsion engine side of combine. The engine and two transmissions are located in front of the rear wheels.

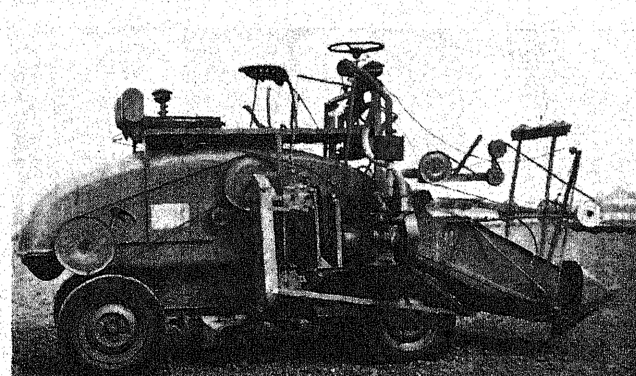


FIG. 2.—Thresher engine side of combine. The engine is located above and back of the front wheel. Threshed grain is collected in the bin which hangs beneath the machine.

[1] Approved for publication as Miscellaneous Paper No. 9 by the Director of the Oregon Agr. Exp. Sta. and the Chief of the Soil and Water Conservation Research Branch, A.R.S., U.S.D.A. Contributions of the Department of Soils and the Department of Farm Crops of OAES and of the Western Section of Soil and Water Management of SWCRB. Rec. for publication Dec. 20, 1954.

[2] A self-propelled plot combine. John B. Liljedahl, N. I. Hancock, and James L. Butler. Agron. Jour. 43:516–517. 1951.

higher than about 9½ feet, and may be transplanted behind automobiles or pickup trucks at legal highways speeds.

The combine cuts a swath 40 inches wide. In fertilizer experiments at this station plots are usually made 8 feet wide and 50 feet long; an area 40 inches wide and 40 feet long (133 square feet) is harvested from the central portion of the plots. Where wheat yields 30 bushels per acre this provides a 5½ pound sample. The combine is employed for trimming the plot ends prior to harvesting plot samples.

During the past season, these combines have been used to harvest experimental plots of wheat, barley, beans, alta fescue, and vetch on approximately 80 farms in various portions of Oregon. Two men are sufficient to operate the combine, but it is convenient to have a third man to tie and label the bags containing threshed samples. Crews of 3 men have harvested 30 to 40 plots (50 feet long) per hour. Liljedahl, Hancock, and Butler estimated the combine resulted in 80% saving of manpower in comparison with hand harvesting. With the cleaning mechanism of the combine carefully adjusted to clean the grain, satisfactory weights for yield determinations may be obtained immediately. Where necessary, grain samples may be quickly cleaned of chaff and straw with a Vogel Re-cleaner.[3]

It is our opinion that portable self-propelled plot combines may be constructed from several other small commercial pull-type combines, but probably none is as compact and light weight as the Allis-Chalmers Model 40. Insofar as we are aware, no implement company is presently manufacturing a commercial combine of a size suitable for conversion into a small portable self-propelled plot combine. Combines of suitable size are only available on the used market. All repair parts are presently available. It is the policy of the larger manufacturers to maintain stocks of repair parts of machines no longer in production for as long as any considerable number of them are in use.

A list of needed materials, drawings, and further description of the Oregon plot combines are available from the authors on request.—ALBERT S. HUNTER and JAMES H. JOHNSON, *Soil Scientist, Oregon Agr. Exp. Sta., and Western Section, Soil and Water Management, SWCRB, ARS, USDA, Corvallis, Oreg., and Farm Foreman, Farm Crops Dept., Oregon Agr. Exp. Sta., Corvallis, Oreg.*

[3] Designed by Dr. Orval A. Vogel, Agronomist, Agricultural Research Service, Agronomy Department, State College of Washington, Pullman, Wash.

GRASS-LEGUME BAND SEEDING WITH A SHOE TYPE DRILL[1]

ESTABLISHMENT of alfalfa, clovers and cool season grasses is often difficult during fall months in southeast Oklahoma. Soil moisture is frequently limiting, with early fall showers usually followed by droughty periods. Low soil fertility is a limiting factor for vigorous seedling growth in most areas. Possibilities of overcoming these hazards to stand establishment include summer fallowing and the seeding of grasses and legumes directly above fertilizer bands in well prepared seedbeds. However, farm equipment now in general use does not offer an efficient means of obtaining precision band seeding with the desired fertilizer placement.

A commercial narrow-furrow, shoe-type drill has proved to be an effective method of accomplishing this band seeding and fertilizer placement, giving excellent stands of tall fescue, orchard grass, brome, alfalfa, Ladino and common white clover mixtures at the Southeast Oklahoma Pasture Fertility Station, Coalgate, Okla. The seedings were made in 2 experimental pasture areas, totaling about 70 acres. The soil types are principally Dennis silt loam and Verdigris silt loam. These fields were fallowed through the driest summer of record and had good subsoil moisture at 10-inch depth prior to the first fall showers. Two tons of lime per acre were applied broadcast and a smooth, firm seedbed was prepared.

A shoe-type drill was rigged to place high analysis fertilizer in a band at a 2-inch depth, with the grass and legume seed falling at the point where the loose soil flowed together behind the furrow opening drill shoe (figure 1). This gave a good distribution of seed in the upper half inch of soil immediately over the fertilizer band. A wide press wheel following each drill shoe firmed the seedings.

An alfalfa-clover seed mixture was dropped with a uniform seeding rate through the grass seed attachment. The grass seed mixture was aplied with excellent precision through the grain box fitted with an agitator. Both grass and legume seed were delivered through a single flexible hose with the opening end held by a clip attached to the rear of the drill shoe. The fertilizer was delivered through a separate flexible hose dropping the fertilizer into the furrow-opening shoe.

An excellent stand of cool season grasses and small seeded legumes was obtained in this manner (figure 2). The use of a narrow-furrow, shoe-type drill offers good possibilities for obtaining precision band seeding for grass and legumes over a deeper placed fertilizer band.

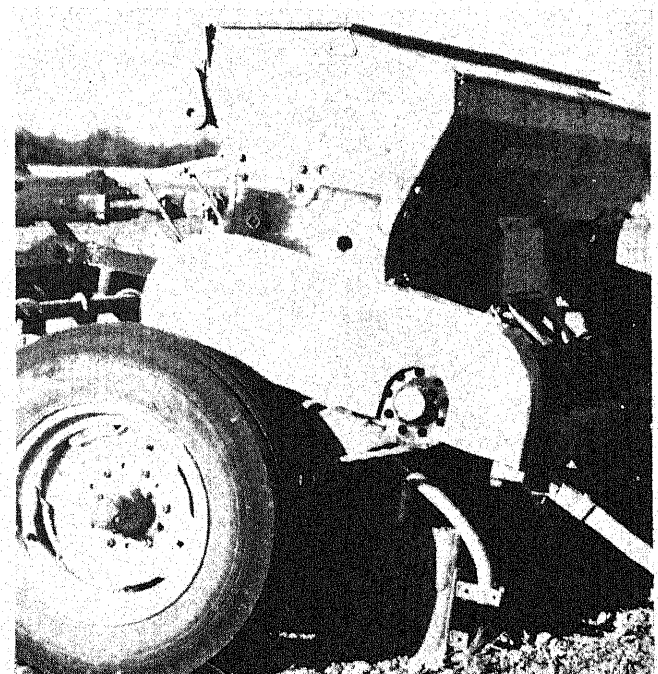


FIG. 1.—A narrow-furrow, shoe-type drill rigged for seeding grass and legume seed directly above a fertilizer band in a prepared seedbed. The small-seeded legume mixture is applied through the grass-seed attachment, and the grass seed is dropped through the grain box fitted with an agitator. Both grass and legume seed are delivered through a single flexible hose dropping the seed at the point where the loose soil flows together behind the drill shoe. The fertilizer is delivered through a separate flexible hose dropping the fertilizer into the furrow opening shoe and placing it in a band at a 2-in. depth. A wide press wheel following each drill shoe firms the seedings.

[1] Rec. for publication Dec. 27, 1954.

FIG. 2.—Cool season grass and perennial legume mixture 6 weeks after seeding directly over a fertilizer band placed at 2-in. depth. Seedings were established in a well prepared seedbed on land that had been summer fallowed. Two tons of lime were applied per acre, broadcast. The fertilizer applied at seeding was 150 lbs. 10–30–10 per acre. The mixture used was 5 lbs. each tall fescue, brome and orchard grass, 9 lbs. alfalfa and 1 lb. each Ladino and common white clover. The vetch seedlings are volunteer form the previous year's rye-vetch crop.

This type of drill has been used in a similar manner to thicken drouth-thinned established alfalfa stands at the Peanut Experiment Farm, Stratford, Okla. Fall stand establishment in that area has a further hazard from the sharp cutting action of wind-blown sand particles on exposed seedlings during the fall and winter months. The older, scattered plants give protection to young seedlings during that period.—J. Q. LYND, *Oklahoma A. and M. College, Stillwater, Okla.*

LETHALITY IN A WHEAT CROSS[1]

LETHAL genetic combinations have been reported in crosses of common wheat varieties,[2] but they occur so infrequently that they are of little importance in breeding programs. They are, however, of considerable genetic interest. The purpose of this note is to report lethality in a cross of two wheat varieties not previously known to carry lethal factors.

Atlas 66, a soft red winter wheat, was crossed with several soft wheat varieties and with Quanah, a hard red winter variety, in the spring of 1952. Seed of the parent varieties and the hybrid seed were fall planted near Raleigh, N. C. Fall growth appeared normal in all F_1 plants. In February the 20 F_1 plants obtained from the cross Quanah $\times$ Atlas 66 appeared to be dying and by the end of March all plants from this cross were dead. There was a gradual yellowing and weakening of the plants and the leaves died from the tip downward. No pathogenic organism or environmental factor could be associated with this condition. The roots appeared normal.

These two varieties were again hybridized in 1953, but only one seed set. This seed, which was from the reciprocal cross Atlas 66 $\times$ Quanah, was planted with the two parents. The F_1 plant grew normally in the fall, but died in the spring of 1954 as had those in the previous year.

Since Atlas 66 and Quanah, as well as parents and F_1 plants of other crosses grown under the same conditions, were normal, it was concluded that lethal genetic factors were operating in the cross.

These lethal factors appear to be different from those reported by Caldwell and Compton,[2] who found that seedlings with lethal factors invariably died soon after the four leaf stage. Most of the F_1 plants of the cross reported here reached a height of 8 to 12 inches with several tillers before they died. There is a possibility, however, that the difference in stage of development of the plants at the time of death was due to differences in environmental conditions. The amount of growth was somewhat comparable to the semi-lethal condition described by Sachs[3] in some interspecific wheat crosses. He found, however, that an occasional plant in these crosses would produce a single head, whereas none of the plants reported here reached the heading stage.—T. T. HEBERT and G. K. MIDDLETON, *Associate Professor of Plant Pathology and Professor of Agronomy in Small Grain Breeding, respectively, North Carolina Agr. Exp. Sta.*

[1] Rec. for publication Dec. 9, 1954.

[2] Caldwell, Ralph M., and Compton, L. E. Complementary lethal genes in wheat. Jour. Heredity 34:67–70. 1943.

[3] Sachs, Leo. The occurrence of hybrid semi-lethals and the cytology of *Triticum macha* and *Triticum vavilovi*. Jour. Agr. Sci. 43:204–213. 1953.

Book Reviews

SMALL FRUIT CULTURE, THIRD EDITION

By James Sheldon Shoemaker. New York, McGraw-Hill Book Co. 447 pp. 1955. $6.50.

This third edition of Prof. Shoemaker's text is an up-to-date handbook of information on small fruit culture which should be a good reference for individual gardeners as well as for commercial growers. Included are separate sections on grapes, strawberries, brambleberries, currants, gooseberries, blueberries, and cranberries. For each type the information includes a brief history of the particular culture, a list and description of varieties in the United States and Canada, methods of propagation, harvesting and handling, and other cultural instructions. The revision brings the book up-to-date on the newest varieties, the latest disease control methods, and irrigation practices and freezing methods. The book is copiously illustrated, although a few of the half-tone engravings are not of the best quality.

TWO EARS OF CORN—TWO BLADES OF GRASS

By D. H. Killeffer. New York, D. Van Nostrand, Inc. 139 pp. 1955. $4.00.

Jonathan Swift was some 200 years ahead of his time when he wrote that the man who can make two ears of corn and two blades of grass grow where only one had grown before would do greater service to his country than all the world of politicians put together. This book relates in an entertaining fashion how modern scientists, notably chemists, have taken Swift at his word, quantitatively at least, to produce food and fibre in an abundance inconceivable 2½ centuries ago. The author's optimism, with respect to future world supplies, seems limitless; it is based on the phenomenal accomplishments of chemistry already in synthesizing vitamins and antibiotics, and in the fields of food production and technology; and he declares that the creative intelligence which envisioned and accomplished these feats is an inexhaustible resource. The book is a plea for education and training to develop this resource, wherever it manifests itself, to enable science to work new "wonders" which will make today's feats seem trifling. Hydroponics and the synthesis of fats, sugars, etc., are only two fields which, the author predicts, might do away with agricultural production at it is now known. Hydroponics is at a stage today comparable to that of the airplane when the Wright brothers flew their first model, he states. While this is indeed a radical view at the moment, it cannot be disregarded. The abundance which the author foresees could eliminate the need to cry for more *lebensraum:* and the optimistic result would be a world of peace. That the world of politicians might not be able to guarantee peace even with abundance is no cause to discredit Mr. Killeffer's optimism, especially in the face of chemistry's record to date which is the basis for his confidence in the future.

NEW PRACTICAL FORMULARY

By Mitchell Freeman. Brooklyn, N. Y. The Chemical Publishing Co. 377 pp. 1955. $7.95.

This book contains more than 2,500 formulas for a great variety of products marketed under numerous trade-marks. Included are alloys, bleaching preparations, Bordeaux mixture, fumigants, larvicides, cements, glues, cleaning preparations, soaps, laundry specialties, cosmetics and perfumes, candy and food products, inks, paints, stain removers, wall cleaners, and others. The author states that most of the formulas are in use today in the manufacture of the products, and some are newly disclosed in this volume. Of the most practical value to the manufacturer or technical worker, this book would also be helpful to vocational teachers and students. The layman himself would find it extremely interesting and revealing. An introductory chapter describes basic operations of a chemical plant. A helpful appendix lists weights and measures, conversion tables, specific gravity comparisons, and sources of supply.

Agronomic Affairs

MEETINGS

- June 15–17, Annual convention, American Seed Trade Assn., Minneapolis, Minn.
- June 25–27, American Society of Commercial Seed Technologists, Stillwater, Okla.
- June 27–29, North Central Branch, A.S.A., Iowa State College, Ames.
- June 27–30, Association of Official Seed Analysts, Stillwater, Okla.
- June 28–30, Pacific Northwest Regional Fertilizer Conference, Boise, Idaho.
- July 27–29, Northeast Branch, American Society of Agronomy, Pennsylvania State University.
- Aug. 1–6, 3rd International Congress of Biochemistry, Brussells, Belgium.
- Aug. 15–19, American Society of Agronomy and Soil Science Society of America, University of California College of Agriculture, Davis.
- Aug. 29–Sept. 6, International Horticultural Congress, Scheveningen, Holland.

AGRONOMIC MANPOWER REPORT

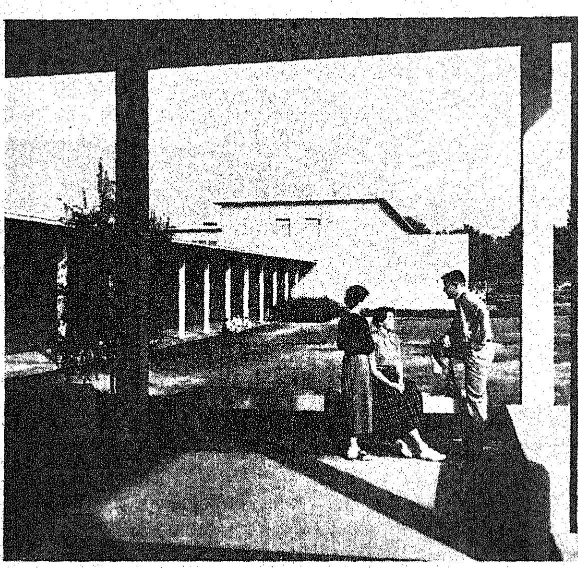
From time to time, members of the Agronomic Manpower Resources Committee receive inquiries relative to the use of scientists in the military, especially as related to Selective Service. People want to know what procedure a young scientist might take, when he is drafted into the military, so that he might be assigned to a scientific activity.

The Army has a scientific and professional personnel program into which it tries to fit engineers and scientists. During the past year, Selective Service has so overloaded the Army with professional personnel that only a fraction of these men are being utilized in any activity remotely related to their specialties. Army officials have been forced to raise the qualifications for assignments in the scientific programs. Most scientists now must have a Master's degree plus a year of experience before they can qualify. Those with Ph.D's are satisfactorily placed. For those interested, direct inquiry can be made to the Chief of Classification and Standards, Branch GI, Department of the Army, Washington 25, D. C.

The Navy and the Air Force do not have comparable set-ups. The Air Force uses a great many men in specialized assignments, but without benefit of such formal arrangements as exists in the Army. The Navy apparently doesn't recognize any kind of specialization except that acquired in uniform.

A STATEMENT OF POLICY

The following Policy Statement looking toward the forging of a realistic manpower program for our country has been endorsed by the Engineering Manpower Commission of Engineers Joint Council, the Scientific Manpower Commission, the Board of Directors of the American Chemical Society and the Technical Manpower Commission of the Armed Forces Chemical Association.



SITE OF THE SOCIETY'S 1955 ANNUAL MEETING—Students chat on a bench of a covered terrace of the Soils and Irrigation Building on the University of California campus at Davis. A covered passageway connects the building with Hunt Hall, which houses the Agronomy Department and the Departments of Vegetable Crops and of Plant Pathology.

The American Society of Agronomy is represented on the SMC through the recently formed Policy Committee for Scientific Agricultural Societies (Agron. Jour. 46:595–596. 1954).

A STATEMENT OF POLICY RELATING TO SPECIALIZED PERSONNEL

When Congress passed legislation to provide for the military strength of our country it declared that "in a free society the obligations and privileges of serving in the armed forces and the reserve components thereof should be shared generally, in accordance with a system of selection which is fair and just and which is consistent with the maintenance of an effective national economy" (Section 1, c of Public Law 51, 82nd Congress).

The obligation and privilege of serving one's country in time of need has appealed to the patriotism of millions, yes billions of people, in literally hundreds of different countries. The United States has no monopoly on this feature. It is in the desire to assure a "fair and just" system of selection that the United States differs sharply from many other nations, and it is particularly important, in the interests of freedom and democracy, that every effort to provide such a system be made. Congress realized this when in the same law (Section 1, e) it declared that "adequate provision for national security requires maximum effort in the fields of scientific research and development, and the fullest possible utilization of the nation's technological, scientific, and other critical manpower resources."

These statements were incorporated into Public Law 51 on June 19, 1951, when the United States was playing a leading role in the Korean action. Since then there has been a gradual change in the world situation and in the part played by the United States. The so-called "cold war" which followed has developed into what more accurately may be called a "technological war." Recent authentic information from Russia indicates that her leaders fear our technological superiority more than anything else. In view of the Russians' greater numerical strength, technological superiority offers the best hope of assuring our national security. It is logical that the degree to which national security can be assured is in direct proportion to our margin of superiority.

While the Soviet Union is conscious of the role of technology as the basis for both military and economic power, it is also conscious of its accomplishments in this area, accomplishments that have eliminated our superiority in certain fields and left the margin uncomfortably narrow in others.

This being true, it is even more certain now than in 1951 "that adequate provisions for national security requires maximum effort in the fields of scientific research and development, and the fullest possible utilization of the nation's technological, scientific, and other critical manpower resources."

THEREFORE: In the interest of immediate as well as long range needs of our nation, it is the opinion of the Engineering Manpower Commission of Engineers Joint Council, the Scientific Manpower Commission, the Board of Directors of the American Chemical Society and the Technical Manpower Commission of the Armed Forces Chemical Association that every step should be taken:

1. To assure maximum and uninterrupted growth of scientific and technological developments by promoting a strong educational system at all levels which will produce an adequate flow of specialized personnel of outstanding qualifications.
2. To assure optimum utilization of specialized personnel through a system whereby both military and civilian needs will be fulfilled. This objective will require expert civilian and military judgment to determine where each person can contribute most to the national interest.

These broad objectives are not being met today. Because they are not being met, it is the opinion of the Engineering Manpower Commission of Engineers Joint Council, The Scientific Manpower Commission, the Board of Directors of the American Chemical Society and the Technical Manpower Commission of the Armed Forces Chemical Association that those in Government having responsibility for the administration of the manpower program should seek:

1. Modification of Public Law 51 (Universal Military training and Service Act) and its administration, including a change in title, in order to guarantee the selectivity features of the law.
2. Legislation to establish a National Manpower Board in the Office of the President composed of both civilian and military personnel whose duty it shall be to determine policy and implement the administration of matters relating to specialized personnel. This legislation shall also provide for proper organization at state and local levels to ensure adequate recognition of individual abilities and local situations which provide realistic proper utilization of each reservist.
3. Legislation to provide an immediately callable reserve, under the control of the military, of such a size that it can be well organized, highly trained, and quickly mobilized to provide an effective striking force in the event of aggression, and also
4. Legislation to provide a selectively callable reserve, whose members shall not be recalled to the military except on a selection basis under the direction of the National Manpower Board.

AGRONOMIC MANPOWER RESOURCES COMMITTEE

W. A. ALBRECHT	J. B. PETERSON
K. H. KLAGES	L. N. SKOLD
W. H. LEONARD	S. A. TAYLOR

C. L. W. SWANSON, *chairman*

HAWAII CHAPTER LISTS ACTIVITIES

The Hawaii Chapter of the American Society of Agronomy has had a busy year, reports R. P. HUMBERT, past president of the chapter. Five meetings were held with attendance ranging from 30 to 78 people. Several interesting programs held during the past year are:

Feb. 4, 1954—"Response to Molybdenum on Legumes in Hawaii" by Dr. O. YOUNGE, and a movie, "Radio Isotopes in Agriculture" by the Atomic Energy Commission; July 30—Dean R. I. THROCKMORTON on "Midwestern Agriculture"; Nov. 9—STERLING HENDRICKS on "Ion Uptake and Utilization by Plants"; Feb. 7, 1955—RICHARD BRADFIELD on "What Factors Limit Yields of Heavily Fertilized Crops"; and March 7—STERLING WORTMAN on "Rockefeller Research in Mexico—Its Implications for Hawaii", and G. DONALD SHERMAN on "Observations on the Soils of Central and South America".

Officers elected for the present year are as follows: KARL F. MANKE, president; ZERA FOSTER, vice president; OTTO YOUNGE, secretary-treasurer; and ERNEST THOMAS, delegate at large.

J. KEITH THORNTON DIES IN PENNSYLVANIA

JOSEPH KEITH THORNTON of Lemont, superintendent of the department of farm operations and service at Pennsylvania State University since 1948, died at his home March 11.

Born May 7, 1905 in McKeesport, he was the son of Charles and Marietta Beman Thornton. He was married to Frances Martin who survives with his mother of Springboro, Pa., and four children, Joseph Keith Jr., Johnstown, and John, Charles, and Mary Faith, all at home.

A brother, one sister, and a grandchild also survive.

Mr. Thornton came to Pennsylvania State University in 1935 as instructor in farm crops after serving for eight years as assistant plant pathologist in the U.S.D.A. Bureau of Plant Industry and the Pennsylvania Department of Agriculture. He was promoted to assistant professor at Penn State in 1941, to associate professor of farm crops in 1944, and to his present post in 1948.

Mr. Thornton, who conducted extensive research on grasses, was graduated from Penn State in 1927 and received his master's degree from the University of Wisconsin in 1947.

He was a member of the Spring Creek Presbyterian Church of Lemont, the Western Crawford Lodge F and AM of Conneautville and the Lemont Lions. He was a member of the College Township School Board for more than seven years and of the College Area School Board until he retired early this year because of illness.

J. L. SCHWENDIMAN RECEIVES AWARD

Plant Material Specialist JOHN L. SCHWENDIMAN received the Junior Chamber of Commerce–Sears Foundation 1954 Achievement in Agriculture award for the state of Washington for his contributions in developing new grasses and legumes for conservation use in the Northwest. For the past 10 years he has been agronomist and manager of the U.S.D.A. S.C.S. nursery at Pullman, Wash., where, in cooperation with State Experiment Stations, 18 improved strains were released. These include Whitmar beardless wheatgrass, Manchar smooth brome, Sherman big bluegrass, Volga wildrye, hard fescue, Topar pubescent wheatgrass, and other new grasses which are now being widely used in conservation seedings.

INDIAN INSTITUTE OBSERVES JUBILEE

The Indian Agricultural Research Institute, New Delhi, popularly known as the Pusa Institute, celebrated its Golden Jubilee April 1–4. The Institute was established in 1905 at Pusa, Bihar, with the help of a donation from the American philanthropist, Henry Phipps. It was located at Pusa until the earthquake of 1934 caused irreparable damage to the laboratory buildings. It was then moved to New Delhi. New laboratories and buildings were opened in November, 1936.

There are at present six major divisions within the Institute: Agronomy, Botany, Soil Science and Agricultural Chemistry, Agricultural Engineering, Entomology and Mycology and Plant Pathology. Recently, the Institute undertook agricultural extension work in Delhi villages. Besides these activities, it co-operates with the Food and Agriculture Organization of U.N. in the maintainance and description of genetic stocks of wheat and with the Technical Co-operation Mission of the United States in conducting trials of certain fertilizers in different parts of India.

OREGON STATION INVITES ANNUAL MEETING ATTENDANTS TO INSPECT RESEARCH AT CORVALLIS

Members of the American Society of Agronomy are invited to view research being conducted at the Oregon Agricultural Experiment Station in Corvallis, Oreg., either before or after the Society's annual meeting at Davis, California, Aug. 15–19.

D. D. HILL, Head of Farm Crops, and H. B. CHENEY, Head of Soils, at Oregon State College report morning and afternoon tours will be conducted daily. Details will be contained in a brochure which will be mailed soon to agronomy and soils departments at other institutions.

COMMITTEES FOR 1955 AMERICAN SOCIETY OF AGRONOMY

(A partial list of Society committees for 1955 was published in the February 1955 issue, page 109, of *Agronomy Journal*)

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NEWS ITEMS

GARTH K. VOIGT left the University of Wisconsin Jan. 4 to take charge of instruction and research in forest soils in a new forest biology program at the Yale School of Forestry, New Haven, Conn. The program is supported by the John A. Hartford Foundation, Inc. Much of the research work will be conducted on a 300-acre tract near Valhalla, N. Y., which the Foundation has leased to Yale University. Prof. Voigt succeeds H. J. LUTZ who has been named director of research under the new program.

—A—

MARVIN D. WHITEHEAD has been appointed assistant professor of field crops at the University of Missouri. He began work in Missouri on March 1. Whitehead received his B.S. and M.S. degrees at Oklahoma A. & M. College and his Ph.D. in plant pathology from the University of Wisconsin. He comes to Missouri from Texas A. & M. College where he has been plant pathologist since 1949.

—A—

B. H. BEARD, Research Agronomist, U.S.D.A., is now located at University of Minnesota's Department of Agronomy and Plant Genetics where he will work on barley breeding and testing.

—A—

R. T. RAMAGE, former teaching assistant in the University of Minnesota Department of Agronomy and Plant Genetics, is now research agronomist, U.S.D.A., at Davis, Calif. His main project will be breeding and genetics of barley.

—A—

ORVIN E. RUD, former research assistant in the University of Minnesota's Department of Agronomy and Plant Genetics, is now research instructor at North Carolina State College. He will work on weed control in soybeans, peanuts, and other crops.

—A—

ROY L. DONAHUS is on leave from the University of New Hampshire, conducting a fertilizer survey in Greece. He expects to return to the United States in June.

—A—

RAY HAMMONS, Purdue forage grass breeder, left March 1 to take a position with the U.S.D.A. in Tifton, Ga. Hammons will be in charge of the peanut breeding improvement program for the Southeastern states. During the 20 months Dr. Hammons was at Purdue, he specialized in the breeding of better strains of brome grass and orchard grass.

—A—

ROBERT T. RAMAGE, who recently received his Ph.D. degree in plant genetics at the University of Minnesota, is now located at Davis, Calif., as Associate in the California Experiment Station, and Agronomist with the USDA Cereal Crops Section. He will conduct work on fundamental barley genetics.

—A—

KENNETH L. VISTE has been appointed as Associate in the California Experiment Station, and Cooperative Agent with the USDA Weed Investigation Section at Davis, Calif., working on rice weed research. He recently received the M.S. degree in Agronomy from the University of California.

—A—

BOYCE C. WILLIAMS was recently appointed Assistant in Agronomy at the New Mexico Experiment Station. He received his Ph.D. degree in soil science at Michigan State College in March. He will do research on sodium soils.

PAUL A. FRYXELL has returned to the New Mexico Experiment Station after a 3-month leave during which he completed the Ph.D. requirements in genetics at Iowa State College. He is now engaged in cotton breeding and genetics.

—A—

HARRY T. BRYANT, who graduated from the University of Maine and also received a M.S. degree from that institution and the Ph.D. degree from the University of Wisconsin, has accepted a position as associate agronomist with the Virginia Experiment Station. He is officer-in-charge of the Northern Virginian Pasture Research Station at Middleburg.

—A—

COLEMAN Y. WARD, a graduate of Texas Tech where he also received the M.S. degree, has accepted a position as assistant agronomist in forage crops research with Virginia Experiment Station at Blacksburg.

PERSONNEL SERVICE

The Personnel Service column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of \$2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a key number which will be carried for five additional insertions unless a discontinue order is received. Items pertaining to soils positions will be inserted one time in the *Soil Science Society of America Proceedings* unless otherwise specified. The following insertions, published in earlier issues, are still available: 11-1, 11-2, 12-1, 1-1, 2-1, 2-2, 2-3.

POSITIONS WANTED

Agronomist (Ph.D., Soil Fertility) experienced in teching (Crops and Soils), research, extension, and conservation, desires position in line with experience and training. Available June 1 or Aug. 15. 4-1

—A—

Agronomist, Ph.D. candidate (will receive degree in June 1955) majoring in Soil Conservation, minoring in Crop Ecology and Land Economics, with teaching and research experience, desires research or teaching position. 4-2

—A—

Agronomist, B.S. in agronomy, University of Kentucky, employed for past 2 years with engineering firm in industrial research and development in Soil Conditioning; good foundation in Soil Physics and Chemistry, Microbiology, and Analytical Chemistry. Prior work for 2½ years with Agronomy Department, Univ. of Kentucky Agricultural Experiment Station, in research on portable irrigation systems for pasture and tobacco land fertilization. Veteran, 29 years old, married, no children. Seeks position in line with above qualifications. 4-3

AGRONOMY JOURNAL

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Articles concerned with instruction, demonstration, experimentation, or research in agronomy will be accepted for publication from members of the Society if deemed suitable by the Editorial Board. It is understood that articles submitted for publication have not appeared previously elsewhere and that they will not be offered for simultaneous publication in other journals without the consent of the Editor of the JOURNAL. At least one author of a paper must be an active member of the American Society of Agronomy.

Free publication in the JOURNAL is limited to four pages, with a charge of $25.00 per page for each additional page. The JOURNAL does not assume financial liability for halftone engravings or zinc etchings beyond $15.00 for each contribution. The author of any otherwise acceptable paper may have it published immediately by paying the entire cost of publication; publication of such a paper does not affect the prority of any paper on the regular schedule.

AGRONOMY JOURNAL

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Influence of Area of Seed Production on the Performance of Ranger Alfalfa[1]

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NEW and improved varieties of alfalfa have been and are being developed for the northern areas of the United States. In the northcentral and northeastern states, alfalfa seed production has not been consistent nor generally successful. Therefore, the National Foundation Seed Project (3) was developed to facilitate the seed increase of new varieties having wide adaptation. The basic stocks of seed of accepted varieties under this plan are made available for the production of certified seed either in or outside the area of adaptation. Although the environmental influences of the various areas of certified seed production on the performance of a new variety have not been fully determined or explained, it is known that some changes do occur when seed of a northern variety is produced in a southern latitude of the United States.

Smith and Graber (6) have compared the performance in Wisconsin of several Ranger alfalfa seed lots. They have shown that seed produced from one generation of increase in southern latitudes of the United States gave stands which produced on the average taller plants following early fall cutting when compared with plants derived from the seed of one generation of increase in the north. Some loss in winter-hardiness was observed also in the plants derived from the southern produced seed. These tendencies were more apparent in plants derived from seed of two generations of increase in southern latitudes. Differences in bacterial wilt susceptibility among the regional seed productions were not noted. Under New York conditions, Murphy and Kohli (5) in a preliminary report state that no significant differences of importance were found among several seed increases of Ranger from Nebraska, Montana, and Arizona with respect to yield, disease reaction, recovery, stand, and vigor except for a lot of second generation Arizona seed not eligible for certification. Battle (1) in studies with Atlantic alfalfa found no significant changes in bacterial wilt reaction that could be ascribed to advance in generation or to area of seed production, but seed from surviving plants in aging stands carried more resistance.

This paper contains further information regarding the performance of plant populations of Ranger alfalfa which were derived from seed produced in several states within and outside the principal region of adaptation of the variety.

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[2] Associate Professor of Agronomy. The author is indebted to Dr. L. F. Graber for helpful suggestions during the course of this work and to Dr. J. H. Torrie for guidance in the statistical phases. The author expresses appreciation to John B. Pitner and Roderic E. Buller of the Rockefeller Foundation, Mexico City, Mexico, for their cooperation in the production of seed for this study, and to Russell F. Johannes at the Marshfield Branch Sta. in Wisconsin for help in maintaining plots at that location. The statistical analyses given in tables 1 and 3 were computed by the Numerical Analysis Laboratory, Univ. of Wisconsin.

MATERIALS AND METHODS

Sixteen regional productions of Ranger were seeded May 15, 1953 in rows 1 foot apart in 4 replications with a randomized complete block design. Check strains included Rhizoma, Narragansett, Buffalo, Caliverde, and Arizona Common. One month after seeding, the plants were thinned to 3 to 5 inches apart leaving an average population of 34 plants per row. The area was kept free of weeds and of new alfalfa seedlings from hard seeds. The foliage was kept free of damaging insects. In this manner, uniform conditions for growth were provided.

Each plant was cut back uniformly to the crown on Sept. 10. Thus, the succeeding growth was produced under the shortening days and cooler nights of autumn. Without disturbing the natural direction of the stem growth, the height of the terminal bud above the soil surface on the tallest stem of each plant was measured in inches on Oct. 7 and 8. This was prior to any frost. The top growth was again cut on Oct. 19. The following spring, winter injury estimates were made in mid-April. Each individual plant was rated on the basis of 100% for a dead plant to 0% for a vigorous and uninjured plant.

Earlier, several regional productions of Ranger were seeded in plots in the spring of 1949 at Madison and at Marshfield, Wis. Check strains included New Mexico Common at Madison, and Grimm, Buffalo, and New Mexico Common at Marshfield. These plots were arranged in a randomized complete block design with 4 replications at Madison and with 3 replications at Marshfield. Observations made in the plot trial at Madison concerning autumnal growth in the seeding year, winterkilling during the first winter, and the first cutting hay yields in June, 1950 were reported earlier (6). Subsequently, hay yields were determined from 3 cuttings in 1950 and in 1951.

Hay yields were not measured in the plot trial at Marshfield. Excellent stands prevailed since no winterkilling had occurred. Therefore, in the fall of 1950, the plots were cut closely and uniformly on Sept. 8 so that comparative observations could be made on the growth made during the shortening days and cooler nights of autumn. On Oct. 7, the height of each individual plant enclosed within a 2-square foot quadrat thrown at random 4 times in each plot in the 3 replications was measured. The stems of each plant were pulled upright and together, and the height of the tallest stem was measured in inches. An average of 164 plants per seed lot was measured.

Differentials in Autumn Stem Growth and Winter Injury in Spaced Populations

The plant height data obtained in the fall of 1953 from the spaced populations at Madison were separated into four groups: short plants, 0 to 2.9 inches; medium, 3.0 to 5.9 inches; tall, 6.0 to 8.9 inches; and the extra tall, 9.0 inches and taller. The percentage of plants in each height group for each seed lot was determined. These percentages were transformed to arc sin $\sqrt{\%}$ for statistical analysis.

Statistical analyses were then made on the percentage of plants in each height group for each seed lot, as well as on the average height of the fall growth and the average percentage of winter injury for each seed lot. No significant differences in performance were found among the plant populations derived from seed lots of Ranger of the same class[3] of seed produced in the same state or pro-

[3] Foundation, registered, or certified seed.

duced from different ages of stands in the same state. An exception was the difference in winter injury between two second generation increases from Arizona (26 and 36%). Significance was found among the different state origins of seed.

The average performances of the Ranger seed lots of the same seed class originating from the same state, and of the check varieties, are presented in table 1. To determine which of the different state origins of Ranger seed differed, the Duncan 5% multiple range test (2) was applied to the means which were the transformed means in the case of the percentage of plants in the height groups. These data are also shown in table 1.

The Ranger plant populations from seed originating from one generation of increase in Montana and Washington (Mont. foundation and Wash. registered) had a large number of plants in the short height group, only a few plants in the tall and extra tall height groups, and only a small amount of winter injury. Plant populations from seed originating from one generation of increase farther south (Cal., Ariz., and Mex. certified) had fewer short plants, more tall plants, and incurred more winter injury. These tendencies were more apparent in the populations derived from Arizona seed than from California seed and were still more pronounced in the populations derived from Mexico seed.

The performance of the Ranger plant populations from seed originating from two generations of increase in Montana and in Arizona was strikingly different. The distribution of the plant population in the second generation increases from Montana (Mont. certified) and the amount of winter injury incurred were virtualy the same as those found in the first generation increases from Montana (Mont. foundation). In contrast, fewer short plants, more tall plants, and more winter injury were noted in the plant populations from seed with two generations of increase in Arizona (not eligible for certification) than were found even in the first generation increases from Arizona (Ariz. certified). The tendency toward tall plants in the population after two generations of increase in Arizona as compared with two generations of increase in Montana is shown clearly in figure 1.

In addition to Ranger, two regional seed productions of Rhizoma were studied. The plant population data (table 1)

Table 1.—Average height of the fall growth and the average percentage of plants falling into 4 height groups in several regional productions of Ranger, in 2 regional productions of Rhizoma, and in 4 check varieties, grown as individual plants from seed in 1953 and measured in October, 1953, and the average percentage of winter injury occurring over winter, 1953–54.

Variety	State or country in which seed class* was produced		Generations in state or country	No. of seed lots tested	Seed produced from*	Ave. height of plants in inches	Percent plants in height groups				Percent winter injury
							0–2.9 in.	3.0–5.9 in.	6.0–8.9 in.	9.0 in. and taller	
							Short	Medium	Tall	Extra tall	
Ranger	Montana	F	1	2	Nebr.F§	3.4	39	52	9	0	8
	Washington	R	1	2	Mont.F	3.5	37	52	10	1	7
	California	C	1	3	Mont.F	3.8	31	52	15	2	13
	Arizona	C	1	3	Mont.F	4.1	28	50	19	3	19
	Mexico†	C	1	2	Mont.F	4.9	16	52	23	9	23
Ranger	Montana	C	2	2	Mont.F§	3.6	38	51	9	2	7
	Arizona‡		2	2	Ariz.C	5.3	13	49	29	9	31
Rhizoma	Canada		–	1	———	1.8	80	18	2	0	1
	Mexico†		1	1	Canadian	2.9	54	39	5	2	8
Narragansett	Rhode Island		–	1	———	2.6	62	31	6	1	2
Buffalo	Kansas		–	1	———	5.4	9	48	35	8	20
Caliverde	California		–	1	———	7.2	2	24	48	26	76
Common	Arizona		–	1	———	10.3	0	4	21	75	93
Coefficient of variability						13%	20%	19%	23%	50%	21%

Significance among the plant population means for the different state origins of Ranger seed using the Duncan 5% multiple range test‖

Average height of plants in inches:
Mont.F. Wash.R. Mont.C. Cal.C. Ariz.C. Mex.C. Ariz.‡

Percent short plants:

Percent tall plants:

Percent extra tall plants:
Mont.F. Wash.R. Mont.C. Cal.C. Ariz.C. Mex.C. Ariz.‡

Percent winter injury:

* F = Foundation seed, R = Registered seed, C = Certified seed.

† Seed produced by the Rockefeller Foundation at Mexico City, Mexico, under the 1950 standards of the International Crop Improvement Association for production of certified seed.

‡ Second generation of increase in Arizona and not eligible for certification.

§ Information not available for one of the seed lots.

‖ Any two means not underscored by the same line are significantly different and any two means underscored by the same line are not significantly different. No significance was obtained for the medium height group of plants.

indicate that there was a shift toward taller plants following one generation of increase in Mexico of Canadian Rhizoma from British Columbia, and that somewhat more winter injury was sustained in the plant population derived from Mexico seed than in the plant population from Canadian seed.

Winter Injury in the Height Groups

The average percentages of winter injury for the Ranger plants in each of the four height groups for the various state origins of seed are given in table 2. These data are based on 3 replicates since an error in plant marking was made in one replicate. The amount of winter injury increased in the plants in each of the four height groups as the Ranger seed originated from a more southern area. Although some of the tall and extra tall plants were uninjured, a higher percentage of these plants was dead or injured than in the shorter height groups.

Differentials in Autumn Stem Growth in Plot Trials

The average height of the autumn growth and the percentage of plants which fell in three height groups (short, medium, and tall) for each seed lot measured in the fall of 1950 in the plot trials at Marshfield were analyzed statistically in the same manner as for the spaced plants.

Essentially the same differences in plant distribution were found in the Ranger height data obtained from stands in plots as were found in the data from spaced plants discussed earlier. No significant differences in performance were found among the plant populations derived from seed lots of the same class of seed produced in the same state or produced from different ages of stands in the same state. Significant differences were found among the plant populations derived from the different state origins of seed. The average performances of the different state origins of Ranger seed, and of the check varieties, are presented in table 3.

In general, there were more tall plants and fewer short plants in the first generation increases from the southern latitudes of the United States than in those from the north. The performance of plants from one northern lot (Idaho registered) differed somewhat from that of other northern stocks. It had a higher percentage of plants in the medium height group and a smaller percentage in the short height group. However, the percentage of tall plants was similar to that in the other northern lots.

The data show also a decided increase in tall plants and a decrease in short plants in the second generation increases from the southern areas as compared with that from the north.

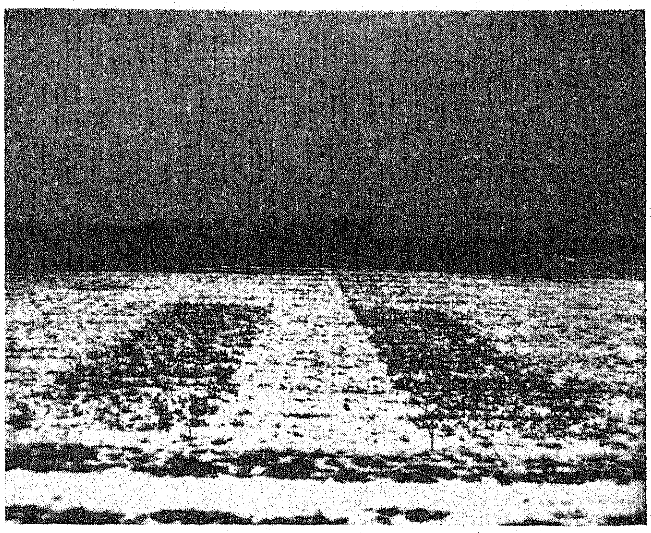

FIG. 1.—A light snow covering brought out the above differences in height of stems after 2 months of growth following cutting on September 9, 1949. Ranger alfalfa (left) from seed derived from two generations of increase in Arizona had many tall plants. Ranger alfalfa (center) from seed derived from two generations of increase in Montana had mostly short plants. New Mexico Common alfalfa (right) had mostly tall plants.

Table 2.—Average percentages of winter injury incurred during the winter of 1953–54 by the plants of Ranger, and of the check varieties, which fell in each of the four height groups shown in Table 1.

Variety	State or country in which seed class* was produced	Generations in state or country	No. of seed lots tested	Plant height groups: 0–2.9 in. Short	3.0–5.9 in. Medium	6.0–8.9 in. Tall	9.0 in. and taller Extra tall
Ranger	Montana F	1	2	6	5	17	—†
	Washington R	1	2	5	6	12	0
	California C	1	3	8	13	22	34
	Arizona C	1	3	15	16	30	37
	Mexico C	1	2	16	15	27	66
Ranger	Montana C	2	2	6	6	5	0
	Arizona‡	2	2	23	24	36	69
Narragansett	Rhode Island	—	1	2	1	10	0
Buffalo	Kansas	—	1	4	19	21	50
Caliverde	California	—	1	33	62	81	84
Common	Arizona	—	1	100	100	100	82

* F = Foundation Seed, R = Registered seed, C = Certified seed.
† No extra tall plants to classify.
‡ Second generation of increase in Arizona and not eligible for certification.

Winter Survival and Hay Yields in Plot Trials

The differentials in winterkilling among plant populations derived from various regional productions of Ranger seed in the plot trial at Madison following the winter of 1949–50 were reported by Smith and Graber (6). The differentials were substantially similar to those reported in this paper for the spaced plant populations. The killing and injury sustained by the stands were also reflected in the yields from the first hay harvest in June (6).

Even though winterkilling occurred during 1949–50, the number of living plants remaining was sufficient to maintain good stands. The surviving plants were well recovered by late July when the second crop of hay was harvested. As a result, there were no significant differences in the yields of hay among the stands derived from the various regional productions of Ranger in the second and third cuttings in 1950, or in the total yields for the year. This was also the case for each hay crop harvested from these plots in 1951 and for the total yields. Evidence of wilt-infected plants was not noted. Moreover, the stands were still good when plowed at 5 years of age but nearly all the plants in nearby plots of wilt-susceptible varieties of the same age had been killed by wilt.

DISCUSSION

The largest proportion of the Ranger alfalfa seed is produced at the present time in the southwestern states where seed yields are very high. This allows a substantial and a continuing supply of seed for forage use in the northern areas but with what appears to be some but apparently not a serious loss in winter-hardiness.

Common alfalfa strains resulting from natural selection during numerous seed generations in southern latitudes of the United States are generally not winter-hardy in the north. Although only one generation of increase is permitted in the southern latitudes for the production of certified Ranger. the performance of plant populations derived from southwestern produced seed has been shown to differ from that of plant populations derived from northern produced seed. The question that arises therefore is what has occurred during seed production to bring about measurable differences between the southwestern and northern produced seed of Ranger. As previously suggested (6), the variety may be responsive differentially to length of day. With the short days during the growing season in southern latitudes, substantially larger amounts of seed may be produced in successive generations from the taller and less winter-hardy

Table 3.—The average height of the fall growth and the average percentage of plants falling into 3 height groups in several regional productions of Ranger alfalfa, and in 3 check varieties, as measured in October, 1950, in plots established in 1949 at Marshfield, Wis.

Variety	State in which seed class* was produced		Generations in state	No. of seed lots tested	Seed produced from*	Ave. height of plants in inches	Percent plants in height groups		
							0–4.0 in. Short	4.1–6.9 in. Medium	7.0 in. and taller Tall
Ranger	Montana	F	1	1	Nebr. F.	5.6	17	60	23
	Oregon	R	1	1	NA‡	5.5	21	54	25
	Idaho	R	1	1	NA‡	5.8	10	65	25
	Utah	R	1	2	Mont. F.	6.2	10	54	36
	California	C	1	4	Mont. F	6.0	8	65	27
	Arizona	C	1	4	Mont. F§	6.4	8	51	41
Ranger	Montana	C	2	1	NA‡	5.6	15	65	20
	Utah	C	2	2	Utah R.	6.5	5	49	46
	Arizona†		2	2	Ariz. C.	7.5	2	25	73
Grimm	Montana		—	1	————	5.7	16	65	19
Buffalo	Kansas		—	1	————	6.4	5	47	48
Common	New Mexico		—	1	————	7.7	4	24	72
Coefficient of variability						5%	27%	9%	15%

Significance among the plant population means for the different state origins of Ranger seed using the Duncan 5% multiple range test‖

Average height of plants in inches:

Oreg.R. Mont.F. Mont.C. Ida.R. Cal.C. Utah R. Ariz.C. Utah C. Ariz.‡

Percent tall plants:

Percent short plants:

Oreg.R. Mont.F. Mont.C. Utah R. Ida.R. Ariz.C. Cal.C. Utah C. Ariz.‡

* F = Foundation seed, R = Registered seed, C = Certified seed.

† Second generation of increase in Arizona and not eligible for certification.

‡ NA = information not available.

§ Information not available for two of the seed lots.

‖ Any two means not underscored by the same line are significantly different and any two means underscored by the same line are not significantly different. Significance for medium height group of plants not shown since the number in this group was dependent upon the number falling in the short and tall groups.

plants, whereas with the longer days of the growing season farther north, where the components of Ranger were developed, all plants may produce seed more or less alike, generation after generation.

It could be assumed also that some cross-fertilization with the non-hardy and wilt-susceptible southern Common may occur in the southern latitudes. However, no differences in wilt reaction have been observed so far among the plant populations derived from various regional seed productions of Ranger, and the differences in winter-hardiness have not been large. The possibility of some cross fertilization with southern Common cannot be dismissed completely, however, because of the foraging habits of the honey bee under stress for pollen, as indicated by the work of Williams and Evans (7) with the bumble bee in red clover.

SUMMARY

Studies were made in Wisconsin on the performance of plant populations of Ranger alfalfa derived from seed which had been produced in several states within and outside the variety's northern region of adaptation.

Significant differences in performance were not apparent among the Ranger plant populations derived from seed lots of the same class (foundation, registered, or certified) of seed produced in the same state or produced from different ages of stands in the same state. The significant differences were among the different state origins of seed.

Ranger alfalfa seed (certified) originating from one generation of increase in southern latitudes produced a greater number of tall plants and fewer short plants in the populations following early fall cutting and were winter injured more than populations derived from seed originating from one generation of increase in northern latitudes (foundation or registered). These contrasts were even more apparent when the plant populations were derived from seed lots originating from a second generation of increase in a southern latitude.

When plants from each lot of seed were grouped into four categories, viz., those with stems that grew short, medium, tall, and extra tall under the shortening days and cooler temperatures of autumn, the amount of winter injury increased in each group as the seed originated from a more southern latitude. Regardless of latitude, winter injury was more severe in the taller than in the shorter plant height groups.

Fortunately, the observed differences in performance between the plant populations derived from certified seed of Ranger produced in the southern latitudes of the United States and seed produced in the north have not been large. On this basis, certified seed of Ranger originating from the southern latitudes seems to be suitable for forage use in Wisconsin and other northern areas.

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The Relation of the Protein Content of Forage Grasses to Earliness of Flowering[1]

J. T. Sullivan and D. G. Routley[2]

THE percentage of protein decreases as grasses mature. On a given date, a late-maturing plant is, as a rule, higher in protein than an earlier plant which has proceeded farther toward maturity. In a study of different grasses, Phillips *et al.*[3] noted that the late maturing species were lower in protein than early ones, and that a late orchardgrass clone was lower than an early one at a comparable stage of maturity. The significance of this observation is that if early clones of a given species are superior to late ones in a character that makes for quality in forage, then other factors being considered, emphasis should be placed on the production of early rather than of late-maturing strains. The present paper reports the protein content of individual plants of orchardgrass, reed canarygrass, and timothy harvested at comparable stages of maturity and the relationship between the protein content and the date of harvest.

Orchardgrass

A small space-planted orchardgrass nursery was examined daily and plants showing several heads half-emerged but not completely emerged from the sheath were harvested for analysis, the sample consisting of the entire above-ground portion. Twenty-nine plants were taken, each of a different clone. The earliest ones reached the half-emerged stage on May 13, 1953, and the latest on June 5. The data are presented in table 1. There was a definite downward trend of protein percentage from the early maturing to the late maturing. The correlation coefficient between the percentage protein at the half-emerged stage and the date at which that stage occurred was significant at the 1% level, $r = -0.86$. The plants had been rated as to leafiness; the correlation between leafiness and the date of half-emergence was significant at the 1% level, $r = 0.52$; that between leafiness and protein percentage was not significant, $r = -0.14$.

Plants from the same nursery were also selected at full bloom. Among 37 plants, each of a different clone, there was again a progressive downward trend of protein from the earliest to the latest. The data are in table 1. The correlation coefficient between percentage protein at full bloom and the date at which that stage occurred was highly significant, $r = -0.68$. The correlation between leafiness and date of full bloom was significant, $r = 0.43$; that between leafiness and protein percentage was not significant, $r = -0.11$.

Twenty-five different clones were common to both the one-half emerged and full bloom groups. The correlation coefficient between the percentage of protein at the half-emerged stage and that at full bloom, in these 25 clones only, was highly significant, $r = 0.63$.

Reed Canarygrass

Spaced plants of reed canarygrass in a large nursery were harvested in 1954 when 8 to 12 heads were visible per plant. The first 2 plants were harvested on May 24. Thereafter harvesting was limited to 6 plants, taken at random, each day when weather permitted up to June 11. With 3 more on June 13, there was a total population of 107. Protein ranged from 8.1 to 16.5%, an average of 12.1. The correlation between protein and date of heading was not significant, $r = 0.05$.

Eight plants were found which contained no, or at most 2, heads per plant and were cut on June 16. They ranged from 8.8 to 13.6% protein, with an average of 11.5.

Timothy

Twelve early timothy plants were sampled when several heads were half-emerged, 7 on June 1, 1954, and 5 the following day. They contained from 8.9 to 12.3% protein, with an average of 10.47 ± 1.02. Twelve late plants taken at a similar morphological stage on June 14, contained 7.3 to 12.4%, with an average of 8.76 ± 1.72. The average difference between the early and late group of plants was not significant.

DISCUSSION

Protein content is only one of the factors which make up the quality of forage for animal feed, but it is one easily measured and is positively correlated with other quality factors. In selecting plants for strain improvement, the later maturing plants have often been favored over early ones because of the superior nutritional quality of the late plants which are more immature at a given date. If the forage is

Table 1.—Protein content of orchardgrass plants, each of a different clone, harvested at the half-emerged stage. The protein content of similar plants harvested at full-bloom.

Half-emerged stage			Full-bloom stage		
Date	Number of plants	Percent protein, average for date	Date	Number of plants	Percent protein, average for date
May 13	8	15.0	May 27	1	8.3
May 14	6	14.0	June 1	1	7.9
May 18	6	11.8	June 2	9	7.3
May 25	1	9.4	June 3	10	7.2
May 27	3	10.3	June 4	3	7.0
May 28	2	10.1	June 5	2	6.6
June 2	2	8.9	June 6	3	7.0
June 5	1	8.1	June 10	3	6.2
			June 11	1	6.8
			June 16	3	6.4
			June 22	1	5.6

[1] Contribution No. 141 of the U. S. Regional Pasture Research Laboratory, Field Crops Research Branch, ARS, USDA, University Park, Pa., in cooperation with the 12 Northeastern States. Rec. for publication Nov. 26, 1954.

[2] Physiologist and Agent. The authors acknowledge the assistance of Dr. H. L. Carnahan for advice and for rating the orchardgrass plants as to leafiness. Dr. H. R. Fortmann of The Pennsylvania State University generously gave us access to the reed canarygrass and the timothy plants.

[3] Phillips, T. G., Sullivan, J. T., Loughlin, M. E., and Sprague, V. G. Chemical composition of some forage grasses. I. Changes with maturity. Agron. Jour., 46:361–369. 1954.

to be harvested for hay or silage the relative composition of the plant at the same or a comparable stage of development should be considered by the plant breeder.

In orchardgrass, high protein was associated with earliness. The population studied was small but differences between early and late plants were great. Since protein is positively correlated with digestible energy, carotene, and essential minerals, it is probable that the early orchardgrass plants have some superiority in nutritive value. Early orchardgrass strains, when grown in sod, are also generally higher yielding than presently available late strains. Late plants, on the other hand, even though more leafy, were lower in protein. This fact alone does not make them less desirable as forage if their content in digestible substances is high. Only feeding trials can determine this point.

No significant differences in protein were found between early, intermediate, and late plants of reed canarygrass when all were studied at the half-emerged stage. A small group of plants which had shown no sign of heading had a level of protein similar to those which did have emerging heads. Phillips *et al.* noted that this species showed less change in composition while passing through various stages of its development than did other grasses. Maturity seems to have less effect on composition in this species.

Significant differences in protein were not found between early and late timothy plants harvested at the half-emergence stage, though only 2 dozen plants were studied. The relationship between time of maturity and plant composition is apparently not the same in all grass species.

SUMMARY

Early maturing orchardgrass plants were higher in percentage protein than late plants when all were harvested at a comparable stage of maturity.

A highly significant correlation, $r = -0.86$, was obtained between the percentage protein of 29 individual orchardgrass plants at the emerged stage and the date when that stage occurred. The correlation coefficient between the protein of 37 plants and the date of full bloom was also highly significant, $r = -0.68$.

No significant relationships were obtained between protein content and earliness or lateness in either reed canarygrass or timothy.

Agronomic Mutations in Oats Induced by X-Ray Treatment[1]

Kenneth J. Frey[2]

THERE has developed in the United States, largely as a result of Swedish publications, a renewal of interest in "mutation breeding" in the cereal crops. From 1930, when Stadler (8) reported upon his experiments with irradiation of cereal grains, until 1950, there was a conspicuous absence of the use of induced mutations in plant breeding in the United States. Meanwhile, plant breeders in Sweden and Germany (1, 5) succeeded in inducing and isolating mutations with agronomic value from X-ray treated barley. Gustafsson (4, 5) published upon several induced beneficial agronomic mutations in barley including a stiff strawed strain called "erectoides," and two or three mutant lines which produced very high yields. The best of these yielded 10% more grain than the parental variety, Gull, and one line showed improved malting quality.

Shebeski and Lawrence (7) have reported a mutant barley strain from irradiated Montcalm variety which is equal to Montcalm in grain production and malting quality, but has shorter and stiffer straw. MacKey (6) obtained a number of the mutant strains from irradiated oats which were earlier and produced higher yields than the parental varieties. Similar results were obtained with wheat.

This paper is a more complete report of an earlier publication by Frey (2) in which beneficial mutations selected from irradiated oats were briefly described. The data presented herein are from only a few of the 61 mutant lines tested. The families of lines shown were selected to illustrate the various agronomic mutations obtained. Only the agronomic mutations will be discussed since a companion paper (3) will deal with the induction of disease resistance mutations in the same materials.

METHODS AND MATERIALS

Four hundred primary seeds of Huron variety of oats containing 9.5% moisture were irradiated with 25,000 r units of X-ray and planted in the field in 1950. Mature X_1 plants were produced from 45% of the irradiated seeds. Each X_1 plant was harvested and threshed separately and in 1951 one row containing 25 spaced plants was planted from each X_1 progeny, resulting in approximately 4,500 X_2 plants which were observed for mutations. Because of the confounding influence of environment on the single plants, it was necessary to save all plants that deviated, even slightly, from the parental variety. The X_3 progenies were sown in plant rows in 1952 and 61 mutant strains which appeared to breed true were grown in yield tests at Ames, Iowa in 1953 and 1954. Plot size was 4 rows wide and 8 feet long with measurements being taken on the 2 center rows. Coefficients of variability for yield in these experiments were 5.0 and 3.5% respectively, in 1953 and 1954. In each year a rather severe epiphytotic of oat stem rust, predominantly race 7, developed resulting in a confounding of the yielding ability and stem rust reaction of the mutant strains.

EXPERIMENTAL RESULTS

The most common mutations found in the irradiated material were fatuoids and vine-type plants. The fatuoids were discarded in the X_2 generation because they were common

[1] Contribution from the Iowa Agr. Exp. Sta., Ames, Iowa. Journal paper No. J-2657. Project 1176. Rec. for publication Dec. 8, 1954.

[2] Associate Professor of Farm Crops; Agronomy Department, Iowa State College, Ames, Iowa.

in non-radiated material and the vine-types proved to be completely sterile.

The most striking and frequent desirable agronomic mutation in the irradiated material was one which produced shortened straw. This is illustrated in tables 1, 2, 3 and 4. The average plant height for all 61 selected mutants grown in the 2 years was 37 inches as compared to 40 inches for Huron. There seemed to be an improvement in the lodging resistance in the mutant lines which probably was related to shortness of straw. The average lodging percentage for the mutant strains was 43% while that for Huron was 70%. These lodging percentages were taken before stem rust was serious; resistance to this disease in the mutant strains probably did not account for the improved straw strength which they exhibited.

In table 2, data are given for two families[3] of X-ray derived lines which appeared to be segregating for test weight. Lines 1, 3, 7, and 8 in family 2 produced good test weight grain when compared with Huron or even Clintland variety. However, line 5 averaged 4 pounds lighter than the other strains in spite of the fact that it had the lowest stem rust coefficient. Apparently there was segregation for test weight genes within family 2 independently of resistance to stem rust. This is ascribed to one or more mutations in this family for improved test weight. Interestingly, all of the selections in family 2 were remarkably uniform for yield, heading date, and plant height, but there was a sizeable range in lodging percentages, from 15% for line 7 to 60% for line 3.

[3] A family was derived from one X-ray treated seed.

Family number 7 also segregated for test weight with line 2 weighing 30 pounds per bushel while the other three lines averaged 24.5 pounds. Furthermore, line 2 yielded intermediate between the low yielding strains, 4 and 5, and the high yielding strain 6. The yield of the strains in this family seemed to be positively related to the stem rust coefficients.

The performance data for family 32 are presented in table 3. Three of the lines yielded somewhat higher than Huron variety and one, line 7, was exceptionally high in yield. All four selections were heavier in test weight, stiffer strawed, earlier, and shorter than Huron variety.

The mutant oat strains most promising for straw stiffness are shown in table 4. The average lodging for these strains was 12% as compared to 70% for Huron variety. Three of the lines were high yielding and one was high in test weight. Line A746–2–7 was the most desirable mutant strain when all agronomic characteristics were considered, since it was high in yield and test weight, and had low lodging percentage. Each of the strains listed in table 4 was resistant

Table 1.—Mean performance of selected mutant oat strains.

Class	Yield (Bu./A.) 1953	Yield (Bu./A.) 1954	Test weight (Lb./Bu.)	Lodging %	Head date	Plant height in.
Mutants	49	89	26	43	June 14	37
Huron	29	59	22	70	June 17	40
Clintland	52	96	31	15	June 13	37

Table 2.—Agronomic performance of oat selections from families segregating for test weight.

Selection	Yield (Bu./A.) 1953	Yield (Bu./A.) 1954	Test weight (Lb./bu.)	Heading date	Plant height (in.)	Lodging (%)	Stem* rust (Coef.)
A 746–2–1	51	94	29	June 14	33	25	5
–3	57	94	32	June 13	32	60	10
–5	57	98	26	June 16	33	33	1
–7	48	96	32	June 14	32	15	3
–8	52	92	31	June 14	32	35	2
A 746–7–2	42	81	30	June 16	36	50	10
–4	34	73	25	June 17	34	87	30
–5	34	69	25	June 17	33	25	30
–6	53	90	24	June 16	33	55	1
Huron	30	59	22	June 19	37	70	20
Clintland	52	96	30	June 15	33	15	10

* Stem rust coefficient is the product of the infection type (read on a scale of 0 to 1, with 1 being fully susceptible) and the percentage of the plant covered by uredia.

Table 3.—Performance of selections in family A746–32.

Selection	Yield (Bu./A.) 1953	Yield (Bu./A.) 1954	Test weight (Lb./bu.)	Lodging %	Head date	Plant height (in.)	Stem rust (Coef.)
A746–32–1	37	83	26	40	June 15	37	20
–2	38	85	27	37	June 15	36	15
–6	37	86	27	10	June 15	37	1
–7	55	106	27	20	June 13	38	1
Huron	29	59	22	70	June 17	40	20

Table 4.—Lodging percentages and other agronomic data for stiff strawed oat mutants.

Selection	Lodging	Yield (Bu./A.)		Test weight	Heading date	Plant height	Stem rust
		1953	1954				
	(%)			(Lb./bu.)		(in.)	(Coef.)
A 746-2-7	15	48	96	32	June 14	32	3
A 746-20-5	20	56	103	27	June 16	33	1
A-746-32-6	10	37	86	27	June 17	34	5
A-746-55-1	12	25	69	28	June 17	30	1
A-746-55-2	5	34	75	26	June 17	30	5
A-746-61-7	12	53	97	27	June 16	33	1
Huron	70	30	59	22	June 19	37	20
Clintland	15	52	96	30	June 15	33	10

to stem rust as indicated by the coefficients for this disease; but this factor did not affect resistance to lodging since the readings were made before stem rust was serious.

Of special interest are the two lines selected from family 55 which, in spite of being resistant to stem rust, yielded little more than Huron. Their lodging percentages, which incidentally were among the lowest for the mutant strains, probably reflected the effect of short straw. A number of spaced plants from the A746-55-2 line grown in 1954 fell into two groups for plant height, one containing plants about 24 inches tall and the other containing those about 32 inches tall. The short plants had both a reduced number of nodes and shortened internodes when compared to the parent variety. The normal number of nodes in a culm of Huron oats is about six when grown in the field, while the culms of the short plants in the A746-55-2 line each had four nodes. The three lower internodes were very short but the uppermost internode was approximately equal in length of that of Huron. For several of the short plants the straw length from the ground surface to the point of head attachment was 12 inches and the head was 14 inches long. A backcrossing program has been started to add complete rust resistance to the short plant type found in A746-55-2. If an oat variety with short straw and normal length heads which would produce high yields could be developed it might be possible to fertilize oats heavily without causing excessive lodging.

The data presented herein are from only a portion of the 61 mutant strains selected from the irradiated Huron material. However, they are representative. At least 50 of the strains are resistant to or segregating for resistance to one or more races of stem rust (3). Several of the lines were high in test weight and several yielded 75% more than Huron variety. It is not proposed that the yield advantage of the mutant strains over Huron is due to the mutation of yield genes, but more probably to the stem rust resistance present in the mutant lines. A majority of the selected strains were earlier and shorter than Huron.

DISCUSSION

The agronomic mutations obtained from X-ray treated Huron oat seed and those obtained by other research workers lead to optimism concerning the possibilities of "mutation breeding" in the cereal crops. Probably the most desirable agronomic mutation found was that for shortened straw which in turn produced resistance to lodging. Many farmers are reluctant to apply the amount of fertilizer, especially nitrogen, necessary to produce high oat yields because it is apt to cause severe lodging. Shorter varieties of oats which resist lodging might aid in overcoming this difficulty. Of course the most desirable short strawed oat mutant strain would be one which retained the desirable agronomic characteristics of the irradiated variety.

In spite of the positive results obtained to date there are several factors about mutation breeding which point out the need for caution in applying this method. First, it is significant that in spite of all of the desirable agronomic mutations induced and selected by Swedish plant breeders, no small grain variety resulting directly from the mutation breeding program has yet been released even though certain strains were proved superior in productive capacity a decade ago. A number of desirable mutant types are being used in the plant breeding program in Sweden, but no mutant strain has been released for commercial production. Second, MacKey (6) has reported that radiation-induced mutant strains in the polyploid cereal grains may be less stable than those selected from hybrid populations. Similar observations have been made on the oat strains reported herein. It has been suggested that this unstability may be due to a deficiency duplication. Third, a large share of the induced mutations obtained from irradiated Huron caused gross changes in more than one morphological or physiological character. This may indicate a pattern of pleiotropic effects of induced mutations, a series of simultaneous mutations, or a general mechanical upsetting of the genotype. If this is common in mutant oat strains produced by irradiation, it may preclude the idea of improving one or two weak characteristics in a variety while retaining the status quo for the desirable agronomic features of the variety.

It is the author's belief that the treating of oats with mutagenic agents will be most beneficial to the plant breeder by increasing the frequency of rare but desirable genes through increased mutation rates. This could be advantageous in three ways. First, desirable genes which are not present in the World Oat Collection and are rare in nature might become available for use in plant breeding program. Second, genes which are infrequent in the World Oat Collection might be induced more or less at will, making it unnecessary to screen this large collection of oats each time a so-called new gene is desired. As an example, the World Oat Col-

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[3] A family was derived from one X-ray treated seed.

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Selection	Yield (Bu./A.) 1953	Yield (Bu./A.) 1954	Test weight (Lb./bu.)	Heading date	Plant height (in.)	Lodging (%)	Stem* rust (Coef.)
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lection at the present time contains 5,000 strains which must be screened for each desired gene. Third, it might be possible to cause variability in seemingly inflexible characteristics, e.g., breaking the tight relationship between amino acids in certain oat grain proteins.

SUMMARY

A number of agronomically desirable mutant strains of oats were isolated from irradiated seed of Huron variety. Some were earlier than the parent variety, while others were from 4 to 7 inches shorter, and lower in lodging percentage. Many of the mutant lines also yielded better than Huron, but this may have resulted from induced mutations for stem rust resistance instead of improved yielding ability. Several lines also were superior in test weight independently of the reaction to stem rust.

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Effect of Planting Date on Yield and Other Characteristics of Soybeans[1]

James H. Torrie and George M. Briggs[2]

THE purpose of this investigation was to determine the response of soybean varieties differing in maturity when planted at several dates. Such information is important for making recommendations to growers and in the interpretation of experiments planted at different dates.

Previous studies (2, 3, 5, 6, 8) indicate that generally early planting gave maximum seed yield. Feaster (3) and Osler and Cartter (6) report that early varieties should be planted later than late varieties for maximum yields, whereas Weiss *et al.* (8) found no significant differences for yield among planting dates of early varieties.

Maturity of late varieties was affected less by late planting than that of genetically earlier varieties (3, 6, 8). Plant height was found to decrease with delay in planting (6, 8). Weiss *et al.* (8) report that date of planting had no effect on lodging whereas Osler and Cartter (6) found an increase in lodging with later plantings. Feaster (3) states that planting date had little influence on seed quality of late varieties but that seed quality was poorest from early plantings of early varieties.

In general a delay in planting resulted in a decrease in oil content (2, 3, 4, 6, 7, 8) and an increase in protein content (2, 6, 7) and iodine number (2, 3, 6, 8). Weiss *et al.* (8) found that protein content was not affected by date of planting. Cartter and Hopper (1) report that the variance for oil and protein content and iodine number contributed by varieties was appreciably greater than that due to locations or years.

[1] Contribution from the Department of Agronomy, University of Wisconsin, Madison, Wis. Rec. for publication Dec. 11, 1954.

[2] Professor and Professor Emeritus of Agronomy respectively, University of Wisconsin, Madison, Wis.; acknowledgment for making all chemical analyses is given the U. S. Regional Soybean Laboratory, Urbana, Ill.

MATERIALS AND METHODS

Five varieties, representative of the range of maturity grown in Wisconsin, were included in the test. Each variety was planted on approximately May 10, May 20, June 1 and June 10 each year during the 5-year period 1945–1949. All plots were located on well drained Miami silt loam soil of good fertility on the University of Wisconsin Farms at Madison, Wis.

The experimental design was a split-plot with four replicates in which dates of planting were whole-plots and varieties sub-plots. Each sub-plot consisted of a single 18-foot row spaced 3 feet from the adjacent sub-plot. Border rows were included between each whole-plot. The middle 16 feet of each sub-plot was harvested for seed yield. Data were obtained on each replicate for agronomic characters, and from a composite of equal proportions from all replicates for the chemical determinations.

The following characters were studied: seed yield, days from emergence to maturity, plant height, lodging index, seed quality index, percentage of oil and protein in the bean, and iodine number of the oil. Date of maturity was when 95% of the pods were ripe. Height was the length of the plant from the ground to the top of the stem at maturity. Lodging was scored on a scale of 1 (erect) to 5 (prostrate) and seed quality on a scale of 1 (very good) to 5 (very poor). The chemical analysis were made by the U. S. Regional Soybean Laboratory at Urbana, Ill.

EXPERIMENTAL RESULTS AND DISCUSSION

The seed yield in bushels per acre, oil percentage, protein percentage and iodine number of the oil are presented in tables 1 to 4 respectively. Days from emergence to maturity, lodging index, plant height and seed quality for each variety at each date of planting averaged for all years are given in table 5. The coefficients of variation shown in tables 1 to 5 are the three factor interactions, varieties × dates × years expressed in percent of the general mean.

Large differences in seed yield were found among varieties, dates and years. The overall interaction of varieties and dates was not significant. However, a significant interaction with dates was indicated when the average of the

Table 1.—Seed yield of 5 varieties of soybeans planted on 4 dates for 5 years, 1945–49, at Madison, Wis.

Date planted	Yields in bushels per acre*					
	1945	1946	1947	1948	1949	Mean
			Flambeau			
May 10	23.4	19.1	22.2	12.9	16.6	19.0
May 20	23.8	19.5	20.8	14.7	25.3	20.8
June 1	25.8	19.3	19.3	14.4	23.1	20.4
June 10	23.9	16.7	15.7	13.7	20.6	18.1
			Mandarin 507			
May 10	28.5	22.1	23.5	17.4	19.8	22.3
May 20	32.3	20.0	22.6	17.6	21.5	22.8
June 1	30.2	21.1	21.5	16.7	27.4	23.4
June 10	32.4	18.5	20.7	15.4	28.9	23.2
			Manchu 606			
May 10	34.2	26.1	28.1	21.3	28.3	27.6
May 20	37.0	26.2	28.3	18.4	31.9	28.4
June 1	34.6	24.2	25.4	17.6	35.0	27.4
June 10	33.5	22.3	24.3	17.3	34.0	26.3
			Manchu 3			
May 10	33.6	24.9	28.3	20.5	25.9	26.6
May 20	37.1	23.6	28.4	17.7	30.3	27.4
June 1	27.9	24.4	23.8	18.9	28.4	24.7
June 10	30.8	21.5	23.0	18.4	33.5	25.4
			Mukden 4			
May 10	39.4	26.0	21.8	19.4	32.3	27.8
May 20	36.3	26.1	27.8	17.9	37.0	29.0
June 1	29.4	23.1	24.2	19.6	38.3	26.9
June 10	28.5	21.2	23.5	15.5	34.7	24.7

* Coefficient of variation = 7.7%.

two early varieties, Flambeau and Mandarin 507, was compared with the average of the three late varieties. Small differences in yield occurred among dates for the two early varieties, whereas a gradual decrease in yield resulted after the May 20 planting for the three later maturing varieties. This agrees with the results reported by Weiss *et al.* (8).

Differences among varieties for oil content of the seed were not consistent for different dates of planting and years. The oil content of Flambeau and Mandarin 507 showed no significant difference between dates whereas for the three later varieties a small but progressive decrease occurred in oil content with delayed planting. The range in oil content between years within a variety averaged over all dates was approximately 1.5% for Mukden and 2.5% for the other varieties. The differential response in oil content of varieties to different seasonal effects is in general agreement with previous results (3, 6, 8).

Large differences were found among varieties and years for protein content of the seed whereas among planting dates the differences were negligible. Differences among varieties were consistent for planting dates but not for years. These results are similar to these reported by Weiss *et al.* (8). The average protein content was highest for the May 10 planting in 1949, for the May 20 planting in 1945, for the June 1 planting in 1947 and 1948, and at the June 10 planting in 1946. The large variety × year interaction is largely due to the difference in protein content of Flambeau and Mandarin 507 as compared to the other varieties; this difference was greater in 1948 and 1949 than in the other years.

Significant differences were found in the iodine number of the oil for varieties, years, and dates. The increase in iodine number with later plantings was consistent for all varieties. Differences among varieties averaged over all dates were not consistent from year to year. The results of other studies (2, 3, 6, 8) indicate an increase in iodine number with later plantings. However, Feaster (3) and Osler and Cartter (6) found that differences among varieties were not consistent, whereas Weiss *et al.* (8) report for three of four tests consistent differences among varieties.

Table 2.—Oil content of seed of 5 varieties of soybeans planted on 4 dates for 5 years, 1945–1949, at Madison, Wis.

Date planted	Oil content, %*					
	1945	1946	1947	1948	1949	Mean
			Flambeau			
May 10	18.5	20.1	20.7	17.5	17.9	18.9
May 20	18.8	20.7	20.3	17.8	18.8	19.2
June 1	18.7	19.8	20.1	18.4	18.3	19.1
June 10	18.4	19.4	21.2	18.5	18.1	19.1
			Mandarin 507			
May 10	17.8	18.9	20.5	17.4	17.3	18.4
May 20	17.7	19.3	20.3	17.3	17.1	18.3
June 1	17.9	19.0	20.0	17.3	17.2	18.3
June 10	17.5	19.6	19.9	17.3	17.8	18.4
			Manchu 606			
May 10	20.2	22.0	22.5	20.0	19.7	20.9
May 20	19.9	21.3	22.4	19.4	19.1	20.4
June 1	19.3	20.5	21.8	19.2	19.4	20.0
June 10	19.1	20.1	21.4	19.6	19.4	19.9
			Manchu 3			
May 10	19.9	21.6	22.4	19.7	19.5	20.6
May 20	19.8	21.0	22.3	19.4	19.6	20.4
June 1	19.5	20.6	21.8	19.1	19.3	20.1
June 10	19.5	19.9	21.3	19.1	19.1	19.8
			Mukden 4			
May 10	19.6	19.7	20.9	19.3	19.5	19.8
May 20	19.4	19.7	20.7	19.4	19.4	19.7
June 1	19.1	19.2	20.4	19.4	19.4	19.5
June 10	18.7	18.8	20.2	18.2	19.5	19.1

* Coefficient of variation = 1.4%.

Table 3.—Protein content of seed of 5 varieties of soybeans planted on 4 dates for 5 years, 1945–1949, at Madison, Wis.

Date planted	Protein content, %*					
	1945	1946	1947	1948	1949	Mean
			Flambeau			
May 10	42.6	41.0	40.2	46.3	45.6	43.1
May 20	42.2	41.0	40.9	46.3	44.7	43.0
June 1	41.8	42.5	41.8	46.6	45.0	43.5
June 10	43.0	42.1	40.0	45.9	44.7	43.1
			Mandarin 507			
May 10	44.4	43.7	40.4	47.3	47.2	44.6
May 20	45.1	43.7	40.5	46.9	46.1	44.5
June 1	45.1	43.5	41.3	47.4	46.2	44.7
June 10	44.9	42.9	41.6	47.4	44.9	44.3
			Manchu 606			
May 10	40.6	38.6	38.4	42.3	41.8	40.3
May 20	41.9	39.2	39.1	43.8	42.0	41.2
June 1	41.2	40.4	40.1	44.5	41.3	41.5
June 10	41.9	40.1	40.5	43.3	40.0	41.3
			Manchu 3			
May 10	39.0	39.0	38.5	43.1	41.6	40.2
May 20	41.2	39.1	39.3	43.8	41.5	41.0
June 1	38.0	42.2	38.4	44.1	40.9	40.1
June 10	39.2	40.1	40.6	43.0	39.5	40.5
			Mukden 4			
May 10	40.1	41.9	41.1	45.1	42.1	42.1
May 20	41.5	41.1	41.3	44.9	39.1	41.6
June 1	39.9	42.2	42.1	44.2	42.0	42.1
June 10	40.5	42.6	40.6	43.7	41.2	41.7

* Coefficient of variation = 1.5%.

Table 4.—Iodine number of oil of 5 varieties of soybeans planted on 4 dates for 5 years, 1945–1949, at Madison, Wis.

Date planted	Iodine number					
	1945	1946	1947	1948	1949	Mean
			Flambeau			
May 10	132.3	127.7	125.2	120.9	122.6	125.7
May 20	132.6	129.7	124.3	122.6	125.4	126.9
June 1	133.2	129.8	122.3	122.8	124.1	126.5
June 10	131.2	131.6	125.9	126.5	128.3	128.7
			Mandarin 507			
May 10	134.0	134.0	126.9	125.2	128.6	129.7
May 20	133.7	131.7	126.3	126.5	130.0	129.6
June 1	133.0	132.6	127.8	126.6	129.4	129.9
June 10	133.8	132.1	130.9	129.3	132.0	131.6
			Manchu 606			
May 10	133.4	132.9	128.0	127.6	131.7	130.7
May 20	133.7	133.0	128.3	129.4	131.2	131.1
June 1	136.0	132.7	128.0	129.3	133.9	132.0
June 10	136.8	135.9	130.2	130.4	135.0	133.7
			Manchu 3			
May 10	135.8	132.1	126.9	127.6	131.4	130.8
May 20	134.5	132.6	128.6	129.2	132.1	131.4
June 1	137.6	133.4	129.1	129.9	134.0	132.8
June 10	138.3	136.0	131.0	130.3	134.7	134.1
			Mukden 4			
May 10	133.3	131.1	127.5	125.3	129.9	129.4
May 20	133.5	132.1	126.4	126.4	130.0	129.7
June 1	136.1	132.9	126.5	126.5	132.2	130.8
June 10	136.9	133.6	128.7	130.2	133.2	132.5

[a] Coefficient of variation = 0.8%.

Maturity was retarded approximately 1 day for each 2 days delay in planting. This was consistent for all varieties which does not agree with other data (3, 6, 8) where maturity date of late varieties was found to be less affected by a delay in planting than that of early varieties.

Date of planting had no effect on lodging. Differences among varieties for lodging were consistent between dates. This was also reported by Weiss *et al.* (8). In general, maximum plant height was obtained at the first planting date with a progressive decrease with delay in planting. Differences among varieties for height were consistent among dates. The findings on plant height are similar with previous results (6, 8). Seed quality tended to be better for all varieties except Mukden, at the later dates of planting.

SUMMARY

Effect of planting at four dates on agronomic and chemical characters of five varieties of soybeans was studied at Madison, Wis., during 1945–1949.

Planting date had little effect on the yield of early varieties whereas for late varieties yield tended to decrease with plantings made after May 20.

Oil content of Flambeau and Mandarin 507 were not affected by planting date while for the later maturing varieties a progressive decrease occurred with later plantings.

Protein content showed no tendency to decrease with delay in planting.

An increase in iodine number, which was consistent for all varieties, occurred with delay in planting.

Table 5.—Average for the 5 years, 1945–1949, of days from emergence to maturity, lodging index, height in inches and seed quality of 5 soybean varieties, planted on 4 dates at Madison, Wis.

Date planted	Days from emergence to maturity	Lodging index	Height in inches	Seed quality
		Flambeau		
May 10	100	2.0	30	2.2
May 20	94	1.9	28	2.2
June 1	90	2.0	28	2.0
June 10	86	1.9	26	1.8
		Mandarin 507		
May 10	107	2.0	34	2.0
May 20	101	1.7	33	2.0
June 1	96	2.0	32	1.6
June 10	92	1.9	32	1.8
		Manchu 606		
May 10	116	2.4	33	1.8
May 20	107	2.6	33	2.0
June 1	104	2.7	31	1.4
June 10	99	3.1	30	1.4
		Manchu 3		
May 10	118	3.1	39	1.8
May 20	112	3.2	38	1.4
June 1	106	3.5	37	1.2
June 10	102	3.4	36	1.6
		Mukden 4		
May 10	128	3.0	42	1.0
May 20	121	3.1	40	1.0
June 1	115	3.3	39	1.2
June 10	111	3.1	37	1.4
* Coefficient of variation	1.3%	15.4%	4.0%	26.5%

Maturity date for all varieties was retarded approximately 1 day for each 2 days delay in planting.

Date of planting had no effect on lodging.

Maximum plant height occurred at the first planting date and decreased consistently for all varieties with later plantings.

Seed quality tended to be better at the later planting dates for all varieties save Mukden.

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Plant Nutrient Competition Between Weeds and Corn[1]

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RECENTLY the idea has been advanced that clean cultivation of field corn is not necessary and perhaps not even desirable (2, 3, 6). Proponents of growing corn without cultivating, point out that the accompanying weed growth controls soil erosion and adds additional organic matter to the soil. By using a specially designed mulch planter, the usual operations in seedbed preparation of plowing, discing, and harrowing are eliminated. Although heavier rates of fertilization are required to supply the nutritional requirements of both the corn and the weeds, the additional cost of the fertilizer is more than offset by savings made in eliminating certain tillage operations.

Thus far, few investigations have been carried out to measure the added requirements of weeds for essential nutrients as well as for moisture, when growing in association with corn plants. Previous investigations by the authors (5) concerning the extent to which common weeds compete with cultural plants for essential plant nutrients, raised serious doubts in their minds about the possibility, to say nothing of the practicability, of meeting the nutritive requirements of cultural plants growing in association with weeds simply by the addition of more fertilizer. The objective of these experiments was to gather some quantitative data relative to this point, particularly with regard to varying rates of phosphate fertilization.

METHODS AND MATERIALS

Field plot experiments were conducted on a Merrimac sandy loam soil in 1952 and 1953. Twenty-five years ago that field had been used for tobacco, but since that time it had been used for hay and pasture with the addition of little or no lime or fertilizer. Consequently, the soil reaction was acid, and the soil was low in available fertility. Fixed phosphorus, however, measured by the citric acid method (1) was high, i.e., 2,000 pounds per acre of fixed P_2O_5. The soil was comparatively free of common arable land weeds.

A randomized block design was used with phosphate fertilizer as the fertilizer variable. Superphosphate (20%) was applied at rates of 0, 50, and 200 lbs. per acre of P_2O_5. Prior to planting, 150 lbs. of nitrogen as ammonium nitrate and 150 lbs. of potash as muriate, both at the acre rate, were uniformly applied. An additional side dressing application of 50 lbs. each of N and K_2O was made a month after planting. Lime as ground limestone was applied uniformly to raise the soil pH to 6.2.

Three common field weeds, pigweed *(Amaranthus retroflexus)*, crab-grass *(Digitaria sanguinalis)*, and barnyard grass *(Echinochloa crusgalli)* and corn were all grown in pure culture, and a mixture of the weed species and corn was grown in plots variously fertilized with superphosphate as previously described. All weeds were seeded in rows 20 inches apart, each thinned to a uniform stand. Corn was drilled 10 inches apart in rows 3 feet apart.

In the corn-with-weeds plots, a mixture of seeds of 3 weed species was broadcast in a band 15 inches wide directly over the corn row. These plots were cultivated, but the weeds surrounding the corn plants were permitted to grow. In the 1953 experiments carried out on a new section of the field, lamb's-quarters *(Chenopodium album)* replaced barnyard grass.

Plant samples for chemical analyses were taken about a month after emergence and again at harvest time. Corn was harvested when the kernels were in the dough stage, and weeds were harvested when 50 to 60% of the seeds were mature.

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RESULTS AND DISCUSSION

Responses to phosphate fertilization by all species were most evident in the seedling stage. In 1952, corn on the high phosphate plots 30 days after emergence was 10 to 15% taller than corn on the low phosphate plots. Weed species, too, responded to phosphate fertilization, with pigweed showing the greatest response followed by barnyard grass and lamb's-quarters. Subsequent yields of dry matter also indicated that each species responded to phosphate fertilization, with pigweed again showing the greatest response (tables 1 and 2).

In 1952, both corn grown alone and corn with weeds responded to phosphate fertilization. However, the relative yields of corn grown with weeds were significantly lower than those of corn grown alone. This was true for all levels of phosphate fertilization. In fact, the relative yields of corn grown with weeds fertilized with 200 lbs. of P_2O_5 per acre were lower than those of corn grown alone with no phosphate fertilization. Since all plots were liberally fertilized with nitrogen and potassium, these results strongly suggest the impracticability or even the impossibility of maintaining corn yields in the presence of weeds by simply increasing the rate of fertilization.

In 1953, responses by all species to phosphate fertilization were more pronounced than in 1952. Pigweed plants, for example, on the low phosphate plots were short, lacked vigor, and generally perished. On plots fertilized with 50 lbs. and 200 lbs. of P_2O_5 per acre, pigweed plants grew well and eventually produced good yields of dry matter (table 2). The most striking results obtained in 1953 were those from the corn-with-weeds plots. Here, the best yields of corn were made on the low phosphate plots. Contrary to the results obtained in 1952, as the rate of phosphate fertilization increased, the yield of corn decreased (figure 1). This is explained by the fact that weeds on the low phosphate plots failed to establish, thus leaving the corn with little competition, not only for phosphorus but also for other nutrient elements and moisture. The moisture factor was probably particularly important because the 1953 growing season was abnormally dry. These results emphasize the importance of available phosphorus in the soil for plants in the seedling stage. They also show that plant species differ markedly in their ability to obtain essential phosphorus from soils low in easily available forms of that element.

The following explanation is suggested to explain the difference in the results for the 2 years. In the first place, weather conditions were markedly different (figure 2). Rainfall in 1952 was normal or above throughout most of the growing season. Rainfall in 1953, in contrast, was abnormally low for the months of June, July, and August. Furthermore, there were differences in the manner in which seedbed preparation was carried out in each year. In 1952, the soil was plowed and limed a year in advance of planting. A nitrogen fertilizer was applied to speed up the decomposition of the old sod. It is reasonable to suggest that the breakdown of organic matter during the year prior to planting released a significant quantity of "fixed" soil phosphorus (4). Hence, responses of corn, for example, to phosphate fertilization were not pronounced.

Table 1.—Relative yields and phosphorus content of corn grown alone and corn grown with weeds variously treated with phosphate fertilizers. (Plots received 200/lb. A. N and 200 lb./A. K_2O).

Year	Treatments	Relative corn yields		Phosphorus content of dry matter			
				Young†		Early maturity†	
	lb./A. P_2O_5	Alone	With weeds	Alone	With weeds	Alone	With weeds
1952	0	100	61	0.27	0.25	0.21	0.21
	50	112	77	0.26	0.22	0.22	0.23
	200	109	84	0.27	0.26	0.23	0.23
1953	0	100	95	0.24	0.25	0.13	0.12
	50	135	56*	0.26	0.25	0.15	0.13
	200	133	58*	0.31*	0.25	0.17	0.16

* Significant in comparison with zero P_2O_5 treatment at 5% level.
† Stage of growth.

Table 2.—Relative yields and phosphorus content of different weeds grown alone and grown with corn variously treated with phosphate fertilizers. (Plots received 200/lb. A. N and 200 lb./A. K_2O).

Plant	Treatment	Relative yields	Phosphorus content of dry matter			
			Young†		Early maturity†	
	lb./A. P_2O_5	Grown alone	Alone	With corn	Alone	With corn
Pigweed	0	100	0.30	0.25	0.22	0.22
	50	154*	0.31	0.30	0.21	0.21
	200	187**	0.42*	0.38*	0.26*	0.26*
Lamb's-quarters‡	0	100	0.34	0.33	0.11	0.11
	50	115*	0.37	0.32	0.13	0.13
	200	139*	0.44*	0.37*	0.18*	0.20*
Crab-grass	0	100	0.28	0.26	0.19	0.17
	50	110	0.28	0.27	0.19	0.18
	200	138*	0.34*	0.30	0.20	0.20
Barnyard grass‡	0	100	0.22	0.24	0.15	0.15
	50	112	0.24	0.23	0.15	0.15
	200	124*	0.30	0.23	0.15	0.16

* Significant at 5% level in comparison with zero P_2O_5 treatment.
** Significant at 1% level in comparison with zero P_2O_5 treatment.
† Stage of growth.
‡ One year's data only.

Table 3.—Nitrogen, potassium, calcium, and magnesium content of corn and weeds. (Air-dry basis. Plots received 200 lb./A. N, 200 lb./A. P_2O_5, 200 lb./A. K_2O. Data are averages of 1952 and 1953.)

Plant	N %		K %		Ca %		Mg %	
	Young	Early maturity	Young	Early maturity	Young	Early maturity	Young	Early maturity
Corn, alone	3.78	1.44	4.02	0.90	0.40	0.17	0.43	0.27
Corn with weeds	3.45*	1.38	3.08**	0.70*	0.42	0.20	0.57*	0.36*
Pigweed, alone	4.36	2.45	4.33	1.80	1.94	0.76	1.90	1.01
Pigweed with corn	4.06	2.52	4.05	2.42*	1.87	0.62	1.78	0.93
Lamb's-quarters, alone†	5.30	2.66	3.92	2.00	1.55	0.70	1.68	0.77
Lamb's-quarters, with corn†	5.12	2.64	4.01	2.50*	1.43	0.75	1.59	0.75
Crab-grass, alone	4.26	2.11	3.96	1.98	0.50	0.34	0.86	0.92
Crab-grass with corn	4.02	2.09	4.17	1.80	0.42	0.38	0.83	0.96
Barnyard grass, alone†	3.82	1.56	2.96	0.98	0.77	0.82	1.15	1.07
Barnyard grass, with corn†	——	1.51	2.88	0.87	0.64	0.63	1.04	1.24

* Significant at 5% level in comparison with grown alone.
** Significant at 1% level in comparison with grown alone.
† One year's data only.

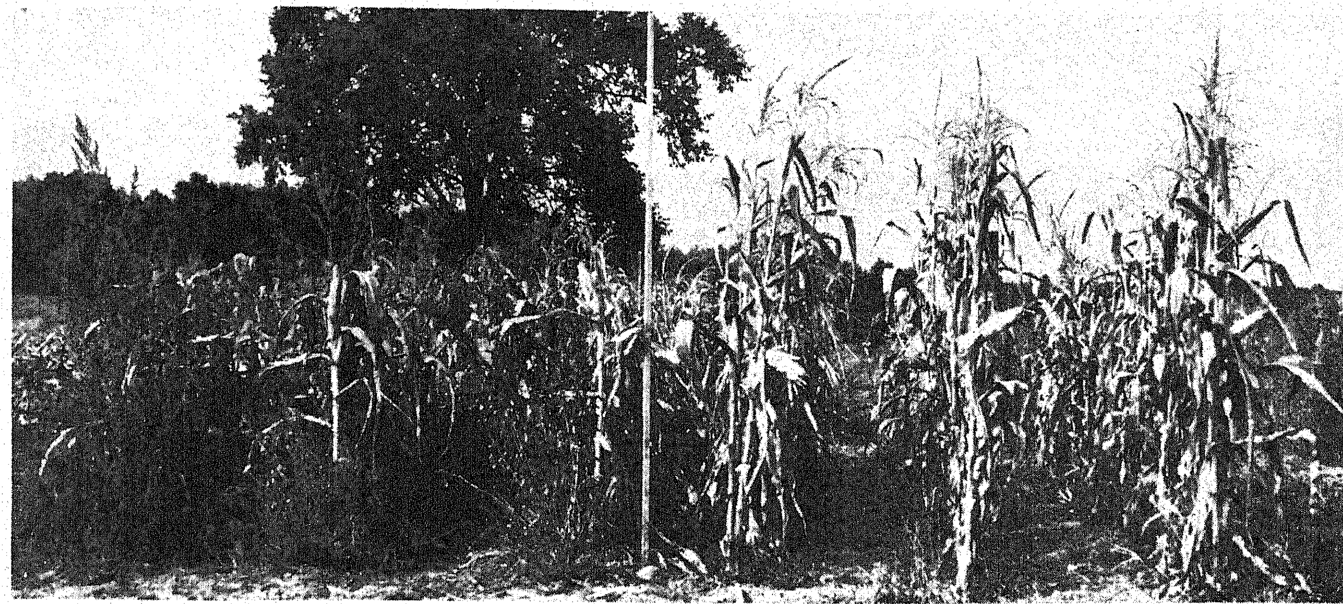

FIG. 1.—In the test plot of corn, left, which received 50 lbs. P_2O_5 per acre, corn is suppressed because weeds were able to establish and compete strongly for moisture and nutrients. In the plot at the right, which received no P_2O_5 treatment, corn growth is normal, and the stand of weeds is poor.

In 1953, the land was plowed late in the fall prior to spring planting. Some lime was applied in the fall and an additional quantity applied the following spring. No nitrogen fertilizer was used to speed up the decomposition of the old sod. Under these circumstances, there was little opportunity for decomposing organic matter to release "fixed" soil phosphorus prior to planting time. The abnormally dry weather later also was undoubtedly a factor that influenced plant growth.

Chemical analyses for phosphorus content of the dry matter reveal certain significant results (table 2). As might be expected, all plants in the young stage of growth are substantially higher in phosphorus content than plants approaching maturity. Additional evidence was obtained to show that plant species differ in their feeding power for soil phosphorus and also in their response to phosphate fertilization. Although the phosphorus content of corn varied only slightly with increased rates of phosphate fertilizer, the phosphorus content of pigweed, lamb's-quarters, and even crab-grass increased substantially as the rate of phosphate fertilization was increased.

Although the only fertilizer variable in these experiments was phosphorus, chemical analyses for N, K, Ca, and Mg (table 3) show rather wide differences in plant composition between corn grown alone and corn grown with weeds. Corn grown with weeds was significantly lower in nitrogen and potassium, particularly in the young plant stage of growth. This occurred notwithstanding the fact that all plots were liberally fertilized with nitrogen (200 lbs. N per acre) and potash (200 lbs. K_2O per acre). Apparently, even at these high rates of fertilization, weeds competed strongly with corn for all essential plant nutrients.

Relative values for yield and total uptake of nutrients by corn grown alone and corn grown with weeds show striking differences (table 4). Corn grown with weeds took up only 47% as much K, 58% as much N, yet produced 63% as much dry matter as corn alone. Table 4 also demonstrates the strong feeding power of some common weeds for potassium, nitrogen, calcium and magnesium.

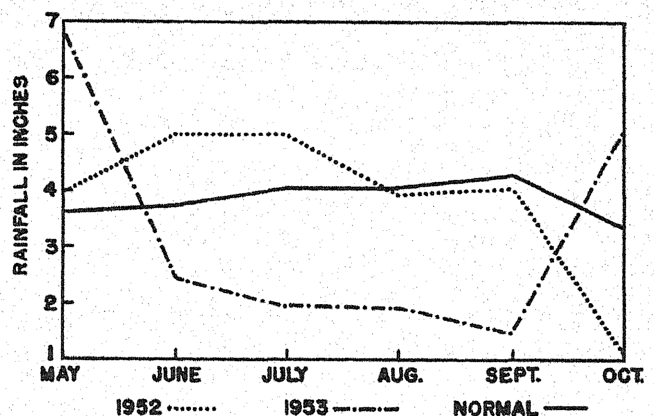

FIG. 2.—Rainfall for the 1952 and 1953 growing season at Amherst, Mass.

Table 4.—Comparison of relative yields and plant nutrient uptake by corn alone, corn with weeds, and different weeds grown alone. (Corn grown alone = 100. Plots received 200 lb./A. N, 200 lb./A. P_2O_5, and 200 lb./A. K_2O. Data are averages of 1952 and 1953.)

Plant	Yields	Relative nutrient uptake (Corn = 100)				
		N	P	K	Ca	Mg
Corn, alone	100	100	100	100	100	100
Corn, with weeds	63	58	63	47	67	77
Pigweed	60	102	80	124	275	234
Lamb's-quarters*	69	120	74	121	281	216
Crab-grass	67	100	64	157	131	228
Barnyard grass*	91	105	60	138	430	337

* One year's data only.

SUMMARY AND CONCLUSIONS

1. Corn grown alone, corn grown with certain common weeds, and weeds grown alone responded to phosphate fertilization. Responses were most pronounced in the seedling stage.

2. Certain species, particularly pigweed, responded greatly to phosphate fertilization. In 1953, pigweed plants on low phosphate plots were weak and failed to grow, and many eventually died. Lamb's-quarters also grew poorly. Because the weeds in this experiment grew poorly in 1953 at low P levels, corn with weeds on the low P plots grew much better and produced much better yields than corn grown with weeds on plots receiving phosphate fertilizer.

3. Even at high rates of fertilization with nitrogen, phosphorus, and potassium fertilizers, weeds competed strongly for essential nutrients, suppressed the growth of corn, and resulted in decreased yields of corn. The feasibility of maintaining high corn yields in the presence of competing weeds by increasing rates of fertilization is strongly questioned.

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Flowering Habit of Alfalfa Clones During the First and Second Growth[1]

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INFORMATION on the flowering habit of alfalfa would appear to be fundamental to seed production research, since flowering precedes the other complex mechanisms that lead to the seed harvest. Preliminary observations of plants in breeding nurseries at Madison, Wis., suggested that inherent differences in flowering habit existed, provided that sucking insects such as the tarnished plant bug, *Lygus oblineatus* (Say), the alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), and the potato leafhopper, *Empoasca fabae* (Harris) were controlled. It was not known if the node at which the first flower appeared on the stem was a stable and significant morphological characteristic of the plant, or if it were variable according to environmental factors. Therefore, the experiment reported here was designed to study the nodal location of the first flowering rachis in different plants during the first and second growth.

METHOD

In September 1950, ten parent plants of different genetic stocks were obtained from a field nursery at the University Hill Farm, Madison, transplanted into pots in a greenhouse, and clipped back. After sufficient regrowth had occurred, 5 stems, having as near to the same number of nodes as possible, were selected from each of the 10 plants. In December, cuttings were made from each node of each stem and propagated in sand in flats. About a dozen cuttings were obtained from a stem. The sequence of node location from the base to the apex of the stem was carefully maintained. After roots had developed, the cuttings were transplanted into flats with soil. When the plants were about 6 inches tall, they were moved from the greenhouse to a cold frame, and held there until transplanted into a field nursery on June 10, 1951. Here it is noted that the cutting from one of the parent plants had largely died out, and it was necessary to carry on the experiment with only nine clones.

The young plants were spaced at 6-inch intervals in rows 24 inches apart and 21 feet long. The plant propagated from the lowest node of stem 1, clone 1, was the first in the row; the plant from the next lowest node was second, etc., so that all of the plants propagated from stem 1, clone 1, were arranged in the row in the same sequence as the nodes on the stem from which they were propagated. This procedure was repeated with the plants propagated from stem 1 of clones 2 to 9, and all considered to be replicate 1. In replicates 2 to 5, the locations of the 9 clones were randomized but the node to node sequence of cuttings within a clone was maintained. The nursery rows were planted in a "S" shaped pattern, giving in effect a continuous row throughout.

Control of sucking and other harmful insects was carried on throughout the growing season with applications of DDT, dieldrin, or other appropriate insecticides. Weeds were kept down by cultivation and hand weeding.

When flowers began to appear on the plants, the first raceme on each of three stems from each individual plant in the nursery was recorded. This reading was obtained by counting the nodes from the first discernible node at the base of the stem up to the node where the first raceme appeared. After readings were obtained in the first growth, the plants were clipped. After the readings were completed in the second growth, the plants were again clipped, but the fall regrowth remained on the plants for winter protection.

The flower counts were made in the first growth periods of early August 1951; June 30 to July 2, 1952; June 16 to 19, 1953; and second growth periods of early September 1951; Aug. 7 to 18, 1952; and July 28 to 29, 1953.

RESULTS

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[2] Associate Professor, Research Assistant, and former Research Assistant; Departments of Agronomy and Entomology, University of Wisconsin, Madison.

Table 1.—Average node location of the first flower: 9 alfalfa clones, I and II growth, 1951–1953.

Clone	Source and Wis. No.	1951		1952		1953		Average
		Early Aug.	Early Sept.	June 30 to July 2	Aug. 7 to 18	June 16 to 19	July 28 to 29	
1	Cossack (45–1)	9.8	8.9	13.6	9.5	14.6	9.2	10.9
2	Cossack (AC–292)	11.8	12.6	14.1	12.1	15.2	12.2	13.0
3	M. falcata (SF–25)	9.9	12.1	12.9	11.0	14.0	10.4	11.7
4	Cossack (45–22)	10.5	10.0	14.2	10.4	15.9	9.7	11.8
5	Grimm (R530)	8.5	8.8	15.3	9.8	16.4	10.1	11.5
6	Grimm (R570)	11.0	13.5	15.1	11.7	17.2	12.1	13.4
7	Cossack (45–44)	10.0	10.0	13.5	9.4	15.6	10.5	11.5
8	Hardigan (R542)	10.0	10.5	14.5	10.7	15.8	12.0	12.3
9	Cossack (A31B–3)	10.8	11.3	13.5	9.8	14.8	10.2	11.7
Average		10.3	10.9	14.1	10.5	15.5	10.7	

flowers appeared on different nodes in different clones, and that during the second and third years there was a very pronounced downward shift of the location of the first flowers in the second growth.

The differences were obtained in the analysis of variance of the data for various sources. Over the 3-year period, the node location on the parent from which the cutting was made had no significant effect on the subsequent node locations of the flowers. However, it was interesting to find that in the first growth of the first year the cuttings in five clones showed significant differences in the location of the flowers. Cuttings propagated from terminal nodes of the stem flowered at lower nodes than cuttings which were propagated from basal nodes. The same cuttings showed no significant differences in the location of the first raceme in the second growth or in subsequent years.

The behavior of these five clones indicates that some physiological factor was present in the first growth that was not present in the second growth. Plant physiologists[3] have suggested the presence of a hormone which controls flowering, and some believe that it is produced in the leaves and stored in the meristematic tissue. Terminal-source nodes flowering at lower nodes than basal-source nodes would suggest that a flowering hormone, if present, remained in the upper portion of the stem and influenced the subsequent flowering habit of the cuttings. If this hypothesis is true, then in this experiment the residual hormone was stored in the stem at or near the node, for in every case all leaves withered and dropped while the cuttings were in the sand flats in the greenhouse.

The differences between years were significant at the 1% level for all 9 clones. All of the interactions of years × nodes and years × nodes × growths were not significant, except for one clone in each interaction, indicating that the clones reacted uniformly over the 3-year period. Difference between first and second growth was significant at the 1% level in all years, and the same was true for a growth × year interaction. The growth × year interaction was further broken down in the analysis and it was found for all clones that the first growth of the first year was significantly different at the 1% level from the first growth in the subsequent years.

The differences shown in the nodal position of the first flowers is believed to be caused primarily by a day-length factor. Flower positions at the 14th or 15th node were associated with long day-length growing conditions. During shorter day-length conditions the flowers first appeared on the stem at about the 10th node. Since the first growth of the first year actually took place in a period similar to the second growth periods of following years, due to the June 10 transplanting date and consequent appearance of flowers in late July and early August, the significant differences which were found are to be expected; and the average position at the 10th node is consistent with the short day-length theory. Differences between the years were probably a result of other variable environmental conditions, such as cloud cover, temperature and rainfall.

Jones[4] showed that the position of flowering in alfalfa differs strikingly among plants, and further suggested that the differences are inherited. Jones reported a characteristic second growth node number within the range of 8 to 11 and stated that plants with a low number are usually earlier in flowering than those with a high number. Data reported here support his observations with respect to genetically controlled flowering differences among plants, but it is believed that the day-length shift is responsible for a greater magnitude of differences in the field than genetic factors. In the 9 clones used in this experiment, the average over-all range of node locations of first flowers was 10.9 to 13.4, and the individual clone extremes were 8.5 to 17.2. The second growth node location averaged 10.7.

SUMMARY

A study of the flowering habit of nine alfalfa clones in a field nursery at Madison, Wis., showed that the nodal appearance of the first raceme on the plant stem was primarily determined both by a day-length factor and inherent differences in the plants.

The shorter day-lengths in the second growth period are principally responsible for the first flower appearing at about the 10th node. Under the longer day-lengths of the first growth period, the flower position was near the 15th node.

The node location on the parent from which the cutting was made had no effect on subsequent node locations of flowers, following the first growth of the first year. In that period immediately following propagation there appeared to be a residual factor in five clones that modified the normal appearance of flowers.

Possible alterations of flowering patterns that might have been caused by sucking insects were prevented by using insecticides for insect control during the experiment.

[3] Hammer, K. C. Hormones in relation to vernalization and photoperiodism. Lotsya 1:63–70. 1948.

[4] Jones, F. R. Internode patterns as a descriptive character in alfalfa. Agron. Jour. 42:432–433. 1950.

SUMMARY AND CONCLUSIONS

1. Corn grown alone, corn grown with certain common weeds, and weeds grown alone responded to phosphate fertilization. Responses were most pronounced in the seedling stage.

2. Certain species, particularly pigweed, responded greatly to phosphate fertilization. In 1953, pigweed plants on low phosphate plots were weak and failed to grow, and many eventually died. Lamb's-quarters also grew poorly. Because the weeds in this experiment grew poorly in 1953 at low P levels, corn with weeds on the low P plots grew much better and produced much better yields than corn grown with weeds on plots receiving phosphate fertilizer.

3. Even at high rates of fertilization with nitrogen, phosphorus, and potassium fertilizers, weeds competed strongly for essential nutrients, suppressed the growth of corn, and resulted in decreased yields of corn. The feasibility of maintaining high corn yields in the presence of competing weeds by increasing rates of fertilization is strongly questioned.

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Flowering Habit of Alfalfa Clones During the First and Second Growth[1]

J. T. Medler, M. A. Massengale, and M. Barrow[2]

INFORMATION on the flowering habit of alfalfa would appear to be fundamental to seed production research, since flowering precedes the other complex mechanisms that lead to the seed harvest. Preliminary observations of plants in breeding nurseries at Madison, Wis., suggested that inherent differences in flowering habit existed, provided that sucking insects such as the tarnished plant bug, *Lygus oblineatus* (Say), the alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), and the potato leafhopper, *Empoasca fabae* (Harris) were controlled. It was not known if the node at which the first flower appeared on the stem was a stable and significant morphological characteristic of the plant, or if it were variable according to environmental factors. Therefore, the experiment reported here was designed to study the nodal location of the first flowering rachis in different plants during the first and second growth.

METHOD

In September 1950, ten parent plants of different genetic stocks were obtained from a field nursery at the University Hill Farm, Madison, transplanted into pots in a greenhouse, and clipped back. After sufficient regrowth had occurred, 5 stems, having as near to the same number of nodes as possible, were selected from each of the 10 plants. In December, cuttings were made from each node of each stem and propagated in sand in flats. About a dozen cuttings were obtained from a stem. The sequence of node location from the base to the apex of the stem was carefully maintained. After roots had developed, the cuttings were transplanted into flats with soil. When the plants were about 6 inches tall, they were moved from the greenhouse to a cold frame, and held there until transplanted into a field nursery on June 10, 1951. Here it is noted that the cutting from one of the parent plants had largely died out, and it was necessary to carry on the experiment with only nine clones.

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The young plants were spaced at 6-inch intervals in rows 24 inches apart and 21 feet long. The plant propagated from the lowest node of stem 1, clone 1, was the first in the row; the plant from the next lowest node was second, etc., so that all of the plants propagated from stem 1, clone 1, were arranged in the row in the same sequence as the nodes on the stem from which they were propagated. This procedure was repeated with the plants propagated from stem 1 of clones 2 to 9, and all considered to be replicate 1. In replicates 2 to 5, the locations of the 9 clones were randomized but the node to node sequence of cuttings within a clone was maintained. The nursery rows were planted in a "S" shaped pattern, giving in effect a continuous row throughout.

Control of sucking and other harmful insects was carried on throughout the growing season with applications of DDT, dieldrin, or other appropriate insecticides. Weeds were kept down by cultivation and hand weeding.

When flowers began to appear on the plants, the first raceme on each of three stems from each individual plant in the nursery was recorded. This reading was obtained by counting the nodes from the first discernible node at the base of the stem up to the node where the first raceme appeared. After readings were obtained in the first growth, the plants were clipped. After the readings were completed in the second growth, the plants were again clipped, but the fall regrowth remained on the plants for winter protection.

The flower counts were made in the first growth periods of early August 1951; June 30 to July 2, 1952; June 16 to 19, 1953; and second growth periods of early September 1951; Aug. 7 to 18, 1952; and July 28 to 29, 1953.

RESULTS

A certain amount of plant mortality occurred during the experiment, which made it impossible to maintain unbroken series in all five replicates of a clone. A preliminary inspection of the data showed that complete series could be obtained by dropping one replicate and eliminating some basal and/or terminal nodes. In the statistical analysis of data the parent plant nodes in unbroken series ranged as follows: 1–8, 1–9, 2–8 (2), 2–9, 3–8, 3–9, 4–9 and 5–11. It was necessary to use 3 replicates only for clone 5.

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The Influence of Awns on Yield and Certain Morphological Characters of Wheat[1]

I. M. Atkins and M. J. Norris[2]

THE influence of awns on the yield of wheat is of practical as well as theoretical interest. If the superiority of either awned or awnless types could be proved without question for a given locality, this information would be of value to the plant breeder for he could then select only the superior type for further testing.

The purpose of this study was to determine the influence of awns on yield of wheat by comparing specially developed awned and awnless lines of wheat in yield tests at Denton, Tex. Four associated factors, number of culms per unit area, size of kernels, test weight, and number of kernels per head were studied to determine their relationships to any differences observed.

REVIEW OF LITERATURE

Numerous comparisons have been made between awned and awnless varieties or groups of varieties. Early comparisons were made simply by comparing pure varieties of the two types;[3] later pedigreed lines were compared (1); and more recently several studies have been made using bulk or specially selected groups of bulk composites from crosses. Bayles and Suneson (3) compared awned and awnless bulk composites from crosses for 5 years at several locations in western United States. The two groups did not yield significantly different but the grain from the awned segregates was superior in both kernel weight and test weight. Finkner and Heyne[3] compared sister awned and awnless selections from F_3 segregating lines of several crosses and from similarly related lines of different backcross populations. Under Kansas conditions, the awned segregates were superior to the awnless group in yield, test weight, and kernel weight.

MATERIALS AND METHODS

Isogenic lines of awned and awnless wheats were developed for this study by a procedure suggested by Atkins and Mangelsdorf (2). This procedure involved crossing an awned variety (Kanred) with an awnless variety (Clarkan). The expression of awns in this cross is controlled by a single gene, and heterozygous plants are recognized by the presence of short awns or tip-awns. Since wheat is self-fertilized, homozygosity for all genes increases in each successive generation following the cross. In this experiment, the gene controlling the expression of awns was kept heterozygous by selection of a large group of tip-awned heads each season.

After 10 generations seed from 10 tip-awned spikes were space-planted, and true breeding awned and awnless lines were selected and increased. These awned and awnless lines from the same tip-awned spike were identical phenotypically except for the awned character. Pairs of lines differed from each other in height, leaf width, leaf color, grain size, and shape. Two pairs that differed in height are shown in figure 1.

Since the awned and awnless members of each pair were so similar after 10 generations of inbreeding, it was assumed that they might be compared for yield and other characters with the assumption that any differences observed might be due to the presence or absence of awns or to genes closely linked with those controlling the awn expression. In all yield tests the awned and awnless lines of each pair were kept together as a unit, and are referred to as a strain in this paper.

The 10 isogenic pairs of lines were grown in a 10 x 10 Latin square planting design with the awned and awnless member of each pair grown side by side in all instances. The strains were randomized in rows and columns with the usual restrictions of the design. The experiment was conducted at Denton, Tex., from 1947 to 1952, but no data were obtained in 1949 or 1951 because of fall and winter droughts. Plots consisted of the usual 4-row nursery plots from which 16 square feet were harvested to determine yield and other measurements.

Data were obtained on yield, stand, weight of kernel, number of kernels per head, and test weight. The stand was determined by counting the number of mature culms per plot. Size of head was determined by threshing individually and counting the number of kernels per spike from 30 heads from each plot. Yield was determined in the usual manner, after which two 1,000-kernel samples were weighed from each plot. By necessity, test weights were taken only on bulked lots from each strain.

Segregates from this cross were susceptible to leaf and stem rusts, and all plantings were dusted with sulfur throughout the season to prevent damage from these diseases.

Weather Conditions

Since awned varieties often are superior under stress conditions, a brief report of the weather during the period of the experiment is presented. The 1947 crop encountered favorable precipitation and temperatures during the fall of 1946, but was under stress in the spring because winter and spring rainfall were deficient and poorly distributed. The 1948 crop gave the highest yields for the period despite below normal rainfall. There was sufficient rainfall to establish the crop, followed by much

FIG. 1.—Two pairs of isogenic awned and awnless lines of wheat from the cross Kanred × Clarkan. Note difference in height by pairs.

[1] Technical paper No. 2117, a report of cooperative research by the Texas Agr. Exp. Sta. and the Field Crops Research Branch, A.R.S., U.S.D.A. Rec. for publication Jan. 10, 1955.

[2] Agronomist, U.S.D.A., Texas Substation No. 6, Denton, Tex., and Associate Agronomist, Bluebonnet Farm, McGregor, Tex.

[3] Finkner, V. C., and Heyne, E. G. A comparison of yield and related agronomic characters between closely related awnless and awned winter wheat segregates. Unpublished paper presented at the annual meeting of the American Society of Agronomy at Fort Collins, Colo., 1949.

Table 1.—Monthly and annual precipitation at Denton, Tex., for the period 1946–52 and averages for the period 1912–52.

Month	Precipitation, inches							40-year average 1912–52
	1946	1947	1948	1949	1950	1951	1952	
January	2.43	0.97	0.56	5.11	4.50	0.59	0.54	2.11
February	4.03	.37	4.86	3.05	2.20	2.29	2.00	2.29
March	3.08	2.98	.70	2.76	.96	.81	2.41	2.32
April	4.35	3.00	.64	.92	4.09	1.67	6.46	3.81
May	7.46	3.19	4.20	7.50	5.95	3.28	4.30	4.62
June	2.63	2.76	2.81	3.85	4.45	5.82	.30	3.11
July	1.31	.00	2.30	2.44	5.83	1.60	1.69	2.07
August	2.37	2.16	.51	2.41	2.36	.64	.34	2.40
September	1.65	2.97	1.10	4.88	3.98	2.49	.27	2.47
October	1.11	2.49	2.33	3.14	.14	2.06	.08	3.03
November	8.17	2.71	.50	.00	.05	1.17	5.07	2.18
December	3.24	5.97	.33	1.84	.04	.36	2.18	2.40
Total	41.83	29.57	19.84	40.87	34.59	22.78	25.64	32.81

above normal rainfall in December, February, and again in May. This provided adequate moisture, and other conditions were favorable. The 1949 and 1951 crops were failures. The 1950 crop season was unfavorable because of a very dry spring. The 1952 season was mild and dry and followed a deficiency of subsoil moisture in 1951. Drought continued through most of the winter of 1951–52, although there was sufficient fall rainfall to establish the crop. Rains came in mid-April in time for the crop to recover and produce better than average yields. The precipitation by months for this period is given in table 1.

RESULTS

Yields

Yields of the awned and awnless segregates of each strain in each season are given in table 2. Least significant differences for each season and for the period of years are also shown.

The awned segregates of each of the 10 strains significantly outyielded the awnless lines in 1947 and 1950. Three awnless lines outyielded their awned sister lines in 1948. In 1952, 6 strains of the 10 awnless lines outyielded their awned counterparts, although the difference was small in most instances. The 4-year average yields of all awned lines exceeded those of the corresponding awnless lines.

The analysis of variance indicates that differences in favor of the awned lines were significant in 1947 and 1950 when the crop was under stress, but not in the other years. The average differences in yield between awned and awnless lines were 2.2 bushels per acre in 1947 and 2.1 bushels in 1950. In 1948, the difference in favor of the awned lines of 1.0 bushels per acre was not significant. In 1952 the difference of 0.5 bushel in favor of the awnless lines also was nonsignificant. Significant seasonal interactions occurred between strains and between awned and awnless lines.

Agronomic Characters

Several agronomic characters were measured in order to determine any possible relationship to yield. The characters measured were weight per 1,000 kernels, number of culms per unit of area or stand, number of kernels per head, and test weight. Weight per 1,000 kernels and test weight apparently were associated with the higher yield in the awned lines. In table 3 are given the data for the 10 pairs of strains for weight of 1,000 kernels, together with least significant differences for each season and for the period of years.

Table 2.—Yields in bushels per acre and differences for paired awned and awnless isogenic lines of wheat from a cross of Kanred × Clarkan, Denton, Tex., 1947–52.

Strain	1947			1948			1950			1952			Average		
	Awned	Awnless	Difference*	Awned	Awnless	Difference	Awned	Awnless	Difference	Awned	Awnless	Difference	Awned	Awnless	Difference
74-44-2	31.6	29.2	+2.4	34.8	35.4	−0.6	20.7	18.5	+2.2	30.0	30.5	−0.5	29.3	28.4	+0.9
74-44-8	29.7	28.2	+1.5	33.0	31.3	+1.7	20.8	17.5	+3.3	30.7	30.6	+0.1	28.6	26.9	+1.7
74-44-9	24.2	21.6	+2.6	33.0	29.6	+3.4	16.7	13.2	+4.5	25.3	24.7	+0.6	24.9	22.3	+2.6
74-44-11	26.2	24.1	+2.1	30.6	33.4	−2.8	17.4	14.7	+2.7	27.6	29.8	−2.2	25.5	25.5	0
74-44-23	28.9	26.0	+2.9	31.8	30.4	+1.4	18.6	18.4	+0.2	31.0	28.5	+2.5	27.6	25.8	+1.8
74-44-24	27.0	24.9	+2.1	36.7	33.3	+3.4	16.9	16.4	+0.5	25.8	25.4	+0.4	26.6	25.0	+1.6
74-44-29	26.7	23.0	+3.7	30.8	28.6	+2.2	17.7	15.4	+2.3	24.3	25.8	−1.5	24.9	23.2	+1.7
74-44-30	26.0	24.0	+2.0	30.7	29.9	+0.8	15.9	13.1	+2.8	24.5	25.6	−1.1	24.3	23.2	+1.1
74-44-32	27.2	25.8	+1.4	33.1	32.4	+0.7	15.2	13.6	+1.6	25.8	27.6	−1.8	25.3	24.7	+0.6
74-44-33	22.4	21.4	+1.0	30.7	31.5	−0.8	17.2	14.8	+2.4	23.9	25.9	−2.0	23.6	23.4	+0.2
Average	27.0	24.8	+2.2	32.8	31.6	+1.0	17.7	15.6	+2.1	26.9	27.4	−0.5	26.0	24.9	+1.1
L.S.D. at 0.05			0.62			1.14			0.66			0.78			0.41
L.S.D. at 0.01			.82			1.52			.87			1.03			.54

* Plus signs indicate increases of awned over awnless lines.

Table 3.—Weight in grams per 1,000 kernel sample and differences for paired awned and awnless isogenic lines of wheat from a cross of Kanred × Clarkan, Denton, Tex., 1947–52.

Strain	1947			1948			1950			1952			Average		
	Awned	Awnless	Difference*	Awned	Awnless	Difference	Awned	Awnless	Difference	Awned	Awnless	Difference	Awned	Awnless	Difference
74–44–2	32.6	30.7	+1.9	35.9	32.3	+3.6	33.7	31.0	+2.7	32.0	30.3	+1.7	32.9	31.1	+1.8
74–44–8	32.0	30.2	+1.8	36.5	33.1	+3.4	34.2	29.8	+4.4	31.8	30.8	+1.0	33.6	31.0	+2.6
74–44–9	27.0	25.7	+1.3	31.6	29.5	+2.1	26.6	23.5	+3.1	27.2	27.2	0	28.1	26.5	+1.6
74–44–11	31.9	29.3	+2.6	35.7	33.7	+2.0	30.8	28.4	+2.4	32.5	30.6	+1.9	32.8	30.5	+1.3
74–44–23	28.6	26.7	+1.9	31.7	27.8	+3.9	25.1	25.1	0	29.1	26.5	+2.6	29.6	26.5	+3.1
74–44–24	29.4	27.1	+2.3	35.2	32.0	+3.2	29.8	26.4	+3.4	29.0	27.7	+1.3	30.9	28.3	+2.6
74–44–29	26.6	26.4	+0.2	30.4	29.1	+1.3	26.7	23.9	+2.8	25.6	26.4	−0.8	27.3	26.5	+0.8
74–44–30	29.1	27.8	+1.3	32.9	31.2	+1.7	29.4	27.2	+2.2	30.2	29.4	+0.8	30.4	28.9	+1.5
74–44–32	29.4	28.4	+1.0	32.5	31.2	+1.3	29.5	26.1	+3.4	30.7	28.5	+2.2	30.5	28.6	+1.9
74–44–33	29.4	28.1	+1.3	34.6	31.0	+3.6	29.9	27.2	+2.7	31.2	29.7	+1.5	31.2	29.9	+1.3
Average	29.6	28.0	+1.6	33.7	31.1	+2.6	30.0	26.9	+3.1	29.9	28.7	+1.2	30.8	28.7	+2.1
L.S.D. at 0.05			0.06			0.27			0.28			0.28			0.04
L.S.D. at 0.01			.07			.35			.37			.37			.05

* Plus signs indicate increases of awned over awnless lines.

Table 4.—Stand, number of kernels per head and test weight for paired awned and awnless isogenic lines of wheat from a cross Kanred × Clarkan, Denton, Tex., 1947–52.

Year	Line	Stand (culms per 16 sq. ft.)	Number kernels per head	Test weight lbs.
1947	Awned	633	17.1	59.6
	Awnless	659	16.6	59.2
1948	Awned	621	18.0	59.6
	Awnless	629	18.7	58.6
1950	Awned	422	16.6	——
	Awnless	439	17.0	——
1952	Awned	535	22.5	——
	Awnless	558	22.9	——
4-year average:				
	Awned	558	18.6	——
	Awnless	571	18.8	——

The weight per 1,000 kernels was higher for the awned lines of the strains in all years and for the average of the 4 years. The difference is highly significant each season. The awned line was higher in all but 3 of the 40 comparisons. The higher kernel weights of the awned strains substantiates the results of other workers.

Relationships of other characters measured were irregular and differences were rather small in many instances. The average number of kernels per head was 18.6 for the awned segregates and 18.8 for the awnless. The awnless lines averaged 571 culms per unit area, compared to 558 for the awned lines. These characters varied from season to season and were not significant in most seasons, but the differences were significant when the data were combined. Data for these characters are given in table 4 for each season and the average for all seasons.

Test weights were higher for the awned lines in 1947 and 1948 which agrees with differences observed in weight of kernel. Test weights were taken only on bulk lots of seed owing to limited supplies of seed.

SUMMARY

The purpose of this study was to determine the effect of awns on the yield of wheat. Ten pairs of specially developed isogenic awned and awnless lines were developed. Each line within a pair was identical phenotypically and genetically except that one line of the pair was awned and the other awnless.

The awned lines produced significantly higher yields, heavier kernels, and higher test weights. The differences in yield and weight of kernels in favor of the awned lines were greater during drought years when the crop was under stress. The differences in number of kernels per head and in stand were non-significant in single seasons but when several seasons were combined they were barely significant.

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Open-Pollinated Seed Setting Among Self-Sterile Clones of Smooth Bromegrass[1]

C. C. Lowe and R. P. Murphy[2]

FORAGE crop improvement is generally concerned with quality and quantity of vegetative production. Recent experience, however, in the introduction of improved varieties of forage crops has indicated that the seed producing ability of a new variety may well decide if it will be increased and distributed. The recent developments of producing seed of forage crops in areas of high seed production make it possible to put new varieties in use on farms very quickly. This can be done most effectively when the seed producing ability of new varieties is known at the time of release. In general, improved varieties should be equal or superior in seed production to the standard varieties in use at the time.

Information on plant characters associated with seed production and refined techniques for measuring these are needed in order to enable forage breeders to screen clones for seed production early in the breeding program. The objective of this study was to determine the association of certain characters of the inflorescence with seed producing ability for a selected sample of self-sterile clones of smooth bromegrass, *Bromus enermis*, Leyss.

The active growth period of most forage grasses consists of two phases—vegetative and reproductive. Although demarcation of the two phases is relatively distinct, both are constituent parts of the normal growth process. The reproductive phase which results in seed production is initiated by natural changes in environment. The developmental morphology for grasses has been described by Evans and Grover (6). A detailed description of the inflorescence in smooth bromegrass is given by Knobloch (10).

Smooth bromegrass enters the reproductive phase only under long day length. Its photoperiodic response has been extensively investigated (1, 5, 7, 11, 12). Induction of tillering and degree of heading are also influenced by temperature. Maturity types and strains within the species have been shown to differ slightly as to optimum temperatures for seed production (5). Soil nutrients, particularly nitrogen, have been shown to have a marked effect on seed production. Watkins (12) and Evans and Wilsie (5) have reported increased shoot and panicle production with nitrogen application. Harrison and Crawford (8) found nitrogen fertilization to cause an increase in seed weight and number of florets per panicle.

Marked differences occur among clones of smooth bromegrass for amount of seed set. This may be attributed in large part to genetic factors affecting cross- and self-fertility. Hill and Myers (9) in an extensive study of North American smooth bromegrass material concluded that the normal chromosome number is $2n = 56$. The species is classed by Elliot and Love (4) as partially allopolyploid. Their study indicated a high degree of meiotic irregularity but they were unable to associate this with pollen fertility.

A study of the species for relationship of seed setting with pollen size, fertility, and chromosome behavior by Cheng (3), indicated that male and female fertility were related and that low seed setting was associated with chromosome abnormalities.

MATERIALS AND METHODS

Thirty clones of smooth bromegrass, previously selected for desirable vegetative characteristics, were used in the study. All were relatively self-sterile as determined by amount of seed set under bag. Inflorescences collected for study were produced in 1948 in a replicated polycross seed production nursery. The nursery was in its second harvest year. Information obtained during the initial seed harvest year made it possible to select for study clones which represented a wide range in open-pollinated seed setting ability.

The polycross nursery containing the clones consisted of 12 replications of single plants spaced 3 feet by 3 feet. Some plants were missing but all the clones that were studied were present in at least eight replications.

A sample of five heads was taken at random from each plant when seed was in the hard dough stage. No attempt was made to keep head size or culm length uniform. After cutting, each head was bent double and placed in an individual envelope. The remainder of the inflorescences on a plant was harvested and bulked with other plants of the same clone for determination of total seed production.

Individual heads were counted for number of florets and number of spikelets contained. Detailed methods which were used in enumerating this volume of material are described by Lowe.[3] After counting, the material from the individual heads was threshed by rubbing between corrugated rubber surfaces and the threshed seeds counted over illuminated glass. Data gathered on number of spikelets, number of florets, and number of seeds were used in computing values for each sample for the following characters:

1. Spikelets per head
2. Florets per head
3. Seeds per head
4. Florets per spikelet
5. Seeds per spikelet
6. Percent fertile florets

The plant values for each character (mean of the five head-samples) were subjected to an analysis of variance to determine clonal differences. Where missing plants occurred, Yates' (13) method of correcting for missing values was utilized.

RESULTS AND DISCUSSION

The clonal means for each of the different characters studied are presented in table 1. The analyses of variance indicated highly significant differences among clones for all characters. Least significant differences are given for comparison purposes.

The clones are ranked in order for production of viable seeds per plant; this was calculated from the actual weight of seed produced and the number of seedlings germinated from a given weight of seed. The figures for viable seeds per plant are considerably lower than those expected from

[1] Paper No. 314, Department of Plant Breeding, Cornell University, Ithaca, N. Y. Acknowledgment is made to the Cooperative G.L.F. Exchange, Inc. for partial support of the work. Presented at the American Society of Agronomy meetings, State College, Pa., Aug. 30, 1951. Part of a thesis submitted by the senior author to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Master of Science. Rec. for publication Jan. 10, 1955.

[2] Assistant Professor and Professor of Plant Breeding respectively, Cornell University.

[3] Lowe, C. C. A study of open-pollinated seed set and of anthesis in self-sterile clones of bromegrass, *Bromus inermis* Leyss. Unpublished M.S. thesis. Cornell Univ. 1950.

the determinations of seeds per head and heads per plant. This came about because the smaller or lighter seeds were either lost in the cleaning of the bulk seed, or failed to germinate or produce a normal seedling. However, the viable seeds per plant determined after cleaning the bulk seed seemed to be the most satisfactory measure of the practical seed producing ability of selected clones.

Seeds per Head

A high positive correlation, r = +0.87, was obtained between the clonal means for seeds per head and viable seeds per plant. Usefulness of this relationship in selecting for seed production seems limited, however, due to the variation in size of individual heads. Samples of the size used in this study (5 heads per plant from each of 12 replications) are impractical if the objective is to screen a large number of clones. Use of the character based on a small sample of heads might be adequate for eliminating low seed producing clones. From the data in table 1 it may be determined that this characteristic did not differentiate well between clones average to good in total seed production.

Florets per Head

Although significant differences between clones in floret number were indicated, the average number of florets per head appeared to be relatively unrelated to total seed production. The correlation value, r = −0.41, is significant at the P = 0.05 level of significance. A study of the data indicated that the low seed-producing clones had slightly more florets per head than did the high seed-producing ones. This may be due in part to a tendency for greater development of terminal florets on plants of low fertility whereas terminal florets on spikelets producing seed tend to remain vestigial.

Spikelets per Head

The means of the clones varied from 41 to 112 spikelets per head. This characteristic was independent of total seed production as indicated by a correlation of r = +0.09. With this group of clones, selection for seed producing ability on the basis of head size would be ineffective.

Florets per Spikelets

Average values for florets per spikelet ranged from 3.4 to 6.9. Although individual spikelets had a wide range in

Table 1.—Average values for seed production characters on 30 self-sterile clones of smooth bromegrass from seed produced at Ithaca, New York, 1948.

Clone No.	Seeds per head	Florets per head	Spikelets per head	Florets per spikelet	Seeds per spikelet	Percent fertile florets	Seed heads per plant	Viable seeds per plant
36	151	250	55	4.6	2.77	60.1	160	10,080
89	180	236	69	3.4	2.60	75.6	123	9,790
103	153	222	48	4.6	3.15	68.0	134	9,775
163	212	280	48	5.9	4.49	75.8	106	8,444
164	194	389	81	4.8	2.40	49.7	105	8,395
77	161	296	59	5.0	2.73	54.1	106	7,775
11	200	340	55	6.2	3.62	58.6	95	7,718
106	189	278	64	4.3	2.95	67.8	62	7,488
116	205	324	75	4.4	2.73	62.9	89	7,487
182	255	473	90	5.2	2.84	54.0	87	6,822
173	215	384	88	4.4	2.45	56.0	101	6,377
166	151	224	49	4.5	3.07	67.6	83	5,940
177	144	456	77	5.9	1.87	32.0	112	5,903
118	191	495	112	4.4	1.72	38.9	85	5,663
117	182	412	75	5.5	2.43	44.0	110	5,350
179	133	327	62	5.2	2.10	40.5	112	4,804
144	116	341	81	4.2	1.42	33.9	94	3,215
99	9	331	65	5.1	.14	2.8	113	2,514
149	34	289	85	3.4	.41	11.7	136	2,415
7	46	403	73	5.5	.64	11.8	110	2,411
189	68	240	64	4.0	1.08	28.7	125	2,280
60	31	220	54	4.1	.58	14.1	113	1,891
147	78	429	79	5.4	1.00	18.2	84	1,590
178	39	309	61	6.0	.64	11.0	59	1,438
79	27	293	52	5.6	.54	9.4	131	1,289
46	9	324	64	5.1	.14	3.0	114	865
132	23	296	43	6.9	.51	7.5	118	782
140	20	409	64	6.3	.32	5.0	99	338
34	10	399	68	5.9	.15	2.6	50	276
9	29	245	41	5.9	.70	11.9	47	156
F for clones	117.79**	27.57**	31.81**	47.67**	290.05**	468.74**		
L.S.D. (P=0.05)	20	42	8	0.35	0.20	3.2		
F for replications	1.49 –	2.23*	1.15 –	2.67**	1.18 –	.09 –		
Correlation with viable seeds per plant r=	0.87**	−0.41*	0.09	−.36*	.90**	.94**	.13	

* Significant at 0.05 level.
** Significant at 0.01 level.

floret number, the clonal differences in this characteristic of the inflorescence were easily observed. Certain clones had long spikelets with high floret numbers, whereas, in others the inflorescence was much branched with the spikelets producing a smaller number of florets. The correlation value, r = −0.36, indicates the same negative relationship with total seed production as found for florets per head.

Seeds per Spikelet

This character was found to be highly correlated, r = +0.90, with total seed production and appeared to be useful as a general measure of a clone's seed producing ability. Beddows (2) has suggested that seeds per 100 spikelets is a desirable criterion for determining seed set in various grasses. This study supports use of the character but does not furnish any evidence on the requisite sample size necessary to measure it (mean values for each of the clones studied are based on counts made on 3,000 to 4,000 spikelets). It seems reasonable to assume that a 100-spikelet sample could be used to give a good relative measure of the seed-producing ability without involving excessive labor. A random method of collection of the sample probably would be necessary since spikelet position on the head and head position on the plant were noted to have some effect on florets produced per spikelet, and, consequently, on seed number. The range among the clones in seeds per spikelet was 0.14 to 4.49. Clones averaging less than 1.5 seeds per spikelet were all relatively low in total seed production.

Per Cent Fertile Florets

Seeds per floret, which is expressed here as percent of florets developing seeds, appeared to give the best index of a clone's seed-producing ability. The correlation of this characteristic with total seed production was r = +0.94. Clonal means ranged from 2.6 to 75.8%. Although there were obvious differences in head size, between head variation was not determined for any character due to limitations imposed by missing plants. Head samples of a clone were observed to vary considerably for the number of florets, spikelets, and seeds they contained, whereas, percent of fertile florets showed very little variation either between head samples or between different plants of a clone. This suggests that this characteristic was relatively stable and was influenced very little by environment in this study.

The F values for replications obtained in the analysis of variance of the data for each characteristic are of interest since they provide information on the relative effect of environment on each of the characters. As each replication was made up of plants from each of the 30 clones, there should have been no differences among replication means from the analyses unless varied conditions of environment such as existed in the nursery actually affected the characters studied. On the other hand, lack of significance for replication means would not rule out the possibility of environmental effects but allows the inference that the different sets of environment (replications) which affected one character affected others differently or to a lesser degree. An examination of the F values indicates that only for number of florets per spikelet and florets per head were the mean values of replications significantly different. It is felt that a favorable environment allows for a greater development of the terminal florets in the spikelet and, consequently, for the head than does an unfavorable one. The F value for replications in the analysis of percent fertile florets was negligible which suggests that this character is primarily genetically controlled.

Seed Heads per Plant

The number of seed heads per plant was determined from counts made on the bulked material used in determining total seed production. Culm number varied from 47 to 160 for the clones studied but had no constant relationship with total seed production as indicated by a correlation of r = +0.13. Undoubtedly, culm number is an important determinant of seed-producing ability, but due to the considerable influence of environment it is difficult to determine inherent differences between clones. Culm production of a clone when grown in spaced plantings and the performance of the clone or its progeny under the highly competitive conditions of row culture or solid stands from which its seed is commercially produced may be relatively unrelated. Grass clones selected on the basis of superior vegetative production frequently appear to be poor headers or produce a disproportionately large number of so-called sterile culms which elongate but produce no seed heads. This is often attributed to nutrient deficiencies at critical stages of head development but may well be due to inadvertent selection against normal seed production while selecting for desirable vegetative types. Data are presently lacking to show whether poor heading on improved strains derived from such parental clones can be overcome in seed producing areas by changes in agronomic practices.

Commercial bromegrass seed varies widely in weight and chaffiness depending on the variety and the season in which it is produced. Different lots may vary several hundred percent in number of seed per given weight. Plants which produce large heavy seeds are desirable since lighter seed is subject to greater losses in cleaning and may produce weak or abnormal seedlings. All seed was processed over standard cleaning equipment. Seed size and weight varied widely for the clones studied, and differential seed loss in cleaning affected the total seed production. This produced some discrepancies in comparisons involving characters where seed was counted without regard to weight.

The occurrence of interannual variation among clones is a distinct possibility, particularly in characters most subject to environment. Percent of fertile florets which seems primarily genetically controlled and shown here to be closely associated with total seed production would appear to be a reliable character for determining seed producing-ability in clones of smooth bromegrass. The 100 spikelet samples suggested by Beddows could be counted for florets as well as seeds without undue difficulty where a better estimate of seed producing ability is desired.[4] Usefulness of the method for evaluating seed set in rows or solid stands of varieties, synthetics, or clonal progenies depends on the variation in fertility among individual plants of a strain. Weights of seed per unit area harvested would probably be most desirable for this type of testing.

SUMMARY

Head samples of 30 self-sterile clones of smooth bromegrass were counted for number of florets, spikelets, and seeds. Clonal differences were determined for seeds per head, florets per head, spikelets per head, florets per spikelet, seeds per spikelet, and seeds per floret expressed as percent fertile florets. The association of each of these characters with total seed production was evaluated. Percent of fertile florets seemed to be most useful as a measure of seed producing ability.

[4] Lowe, *ibid.*

The roles of culm production and seed size were discussed and a suggested method of clonal evaluation given.

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Effects of Cutting First Year Red Clover on Stand and Yield in the Second Year[1]

James H. Torrie and Earle W. Hanson[2]

SPRING seedings of red clover *(Trifolium pratense* L.) often produce abundant growth the first year. Under good growing conditions, the plants may reach a height of 18 to 20 inches and many of them bloom by the middle of September. Numerous inquiries have been received concerning the advisability of mowing such fields prior to the first winter. Studies at Ohio (3, 4, 5) have shown that early cutting may be beneficial but that late cutting usually is detrimental. No such studies have been reported in the United States for areas as far north as Wisconsin.

Willard (3) found that cutting red clover from Aug. 15 to Sept. 1 in the seedling year increased hay yields the next year as compared with fields that were not cut, but that cutting from Oct. 15 to Nov. 1 was usually injurious. Willard (4) and Willard and Lewis (5) reportel that leaving combined straw on the field always resulted in obvious damage to red clover stands, but that cutting the stubble immediately after combining and removing the straw, hay, and weeds never resulted in damage. They further found that it was decidedly better to mow the grain stubble soon after combining and leave it on the field than not to cut it at all. This practice, however, was not as beneficial as removing all material after cutting. Allen (1) reported that clipping red clover in Maryland from mid-August to early September during the seedling year gave better stands and higher yields the second year than when not clipped. Removal of the clippings increased both stand and yield as compared to leaving the clippings on the field.

Nilsson-Leissner (2) made similar studies in Sweden and found that cutting pure stands of red clover in the first week of October of the seeding year reduced yields the following year. He also found that when red clover was grown in mixtures with timothy *(Phleum pratense* L.) or orchardgrass *(Dactylis glomerata* L.), October clipping reduced the total yield of hay the following year in every case but increased the yield of clover in the mixtures in 4 of 6 comparisons. Clipping reduced the yield of Schlesisk, a relatively early-flowering fast growing broad-leaved strain, even when grown in mixtures with grasses. He did not investigate the effects of earlier clippings.

The present study was made to determine under Wisconsin conditions the effects of cutting red clover the first year on stand and yield in the second year, and to compare the effects of removing and not removing clippings from cut plots.

MATERIALS AND METHODS

Seedings of red clover were made on May 7 in 1947, May 13 in 1950, May 7 in 1951, and April 24 in 1952 at the rate of 12 pounds per acre with a companion crop of oats or barley. Barley, seeded at 1 bushel per acre, was used as a companion crop in 1947; oats, seeded at 1½ bushels per acre, was used all other years of these tests. The seedings were made in Miami silt loam on the experimental farms of the Wisconsin Agricultural Experiment Station near Madison, Wis. F.C.13274, commonly called Wisconsin Mildew Resistant, was used in all years except 1947 when a common red clover was seeded. The companion crop was removed at maturity with a binder in 1947 and 1950, and about a week before maturity in the other years with a forage

[1] Contribution from the Departments of Agronomy and Plant Pathology, University of Wisconsin, Madison, Wis., in cooperation with the Forage and Range Section, Field Crops Research Branch, U.S.D.A. Rec. for publication Jan. 10, 1954.

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Table 1.—Tons per acre of oven-dry clippings, including weeds, produced during the seedling year at Madison, Wis.

Date cut	Year			
	1947	1950	1951	1952
Aug. 31	—*	0.57	1.71	1.57
Sept. 15	0.41	0.85	1.76	2.28
Sept. 30	0.69	0.92	1.43	2.31
Oct. 15	0.81	1.06	1.24	1.96
L.S.D. %	0.21	0.22	0.37	0.77
Coefficient of variation	18.7	16.8	14.9	23.8

* No cutting made in August 1947.

chopper. The plots were laid out in fields with uniform stands in a randomized complete block design with four replicates.

Treatments were imposed in the fall of the seedling year and their effects determined the following year. Each replicate was divided into 9 plots; 8 were cut 2½ to 3 inches high with a Jari-mower and 1 was left uncut. Cutting was done on about Aug. 31, Sept. 15, Sept. 30, and Oct. 15. Two plots were cut on each date. The clippings were removed from one and left on the other. In 1947, only three cuttings were made, there was no August clipping.

All plots were 9 by 20 feet in size, except in 1947 and 1948 when they were 15 by 60 feet. Forage yields were based on 6- by 18-foot samples from each plot except during 1947 and 1948 when 10- by 50-foot samples were used. All yields are reported as tons of oven-dry forage per acre. Stand counts were made during late October of the seedling year and the following May. Four random 2- by 2-foot samples were counted per plot on each date.

RESULTS AND DISCUSSION

Growth During Seedling Year

The yields of clippings harvested during the seedling years of these tests are given in table 1. They differed from year to year, as is common in Wisconsin, due to inter-annual differences in precipitation and temperature, length of growing season, date companion crop was removed, and other factors. The 1950 growing season was short; the clover wasn't seeded until May 13 and a heavy frost occurred on September 24. The plants were about 12 to 14 inches tall and had just commenced to blossom when the frost developed. The amount of growth during 1947 was similar to that of 1950; however, a large proportion of the plants had produced considerable bloom when the first frost occurred on Sept. 30. The yields of clippings increased from the first to the last cutting date in both 1947 and 1950. In 1952, the first fall frost did not occur until Oct. 3. Growing conditions were excellent through the month of August but September and October were very dry. The plants were approximately 19 inches tall and blooming had just begun by Sept. 15. Little growth occurred after this date but blossoming increased so that flowers were abundant by Sept. 30. The above ground parts of all plants were severely frozen prior to Oct. 15 which together with the drought caused some loss of leaves and probably accounts for the reduction of yield from Sept. 30 to Oct. 15 (table 1). In 1951, the plants were approximately 22 inches tall, and blossoms were very abundant by Sept. 15. There was little additional growth after this date, even though the first frost did not occur until Oct. 8. The apparent reduction in yield after Sept. 15 cannot be explained entirely on the basis of deterioration. It seems likely that the plots allocated at random to the last two cutting dates were lower in productivity than the other plots.

The weeds present in the forage during all years were predominantly lamb's quarters (*Chenopodium album* L.), the yellow and green bristlegrasses (*Setaria lutescens* (Weigel) F. T. Hubb. and *S. viridis* (L.) Beauv.), barnyard grass (*Echinochloa crusgalli* (L.) Beauv.), ragweed (*Ambrosia artemisiifolia* L.), and rough pigweed (*Amaranthus retroflexus* L.). No attempt was made to separate the weeds from the clover in the fall clippings but the weeds appeared to be larger and more abundant in 1951 and 1952 than in the other years. This was probably because the growing conditions were more favorable and the oats were removed earlier in those years. Also, it may have been due partly to differences in the amount of weed seed present in the various fields at the time the clover seedings were made.

Effect of Management on Stand

The effects of the various treatments on stand of red clover are summarized in table 2. October stands were not significantly different on any of the plots in 1947 or 1950, but were different in 1951 and 1952. In 1951, the uncut plots and those cut Oct. 15 on which the clippings were left had the poorest stands. In the latter case, some of the weaker plants

Table 2.—Effect of nine management treatments on stand of red clover in October of the seedling year and the following May at Madison, Wis.

Treatments*	Average number of red clover plants per 4 square feet on indicated date:							
	Oct. 1947	May 1948	Oct. 1950	May 1951	Oct. 1951	May 1952	Oct. 1952	May 1953
Not cut	46	44	53	41	39	52	35	8
Cut Aug. 31, left	—†	—	57	60	50	68	51	41
Cut Aug. 31, removed	—	—	67	56	52	66	62	64
Cut Sept. 15, left	51	44	45	46	48	48	39	13
Cut Sept. 15, removed	52	39	52	53	53	58	47	30
Cut Sept. 30, left	50	42	61	57	42	38	36	8
Cut Sept. 30, removed	50	42	45	59	45	44	40	22
Cut Oct. 15, left	46	32	57	33	33	34	42	16
Cut Oct. 15, removed	47	35	57	44	46	40	40	26
L.S.D. 5%	N.S.	6	N.S.	N.S.	9	17	8	13
Coefficient of variation	31	21	25	22	14	24	12	35

* Indicates date clipped plots were mowed in the seedling year and whether clippings were left on the plots or removed.
† No data.

died after cutting, apparently due to the smothering effect of the heavy covering of clippings. The lower stands for the uncut plots were probably due to chance in sampling since higher stands were indicated for the same plots the following spring. Best stands in the 1952 test were recorded for the plots cut early and the clippings removed.

Maximum effects of the treatments on stand were seen in the spring following the year of seeding. Stands decreased on all plots during the winter of 1947–48, the reduction being greatest for plots cut Oct. 15. No significant changes in stand occurred during the winter of 1950–1951 except that plots cut Oct. 15 with the clippings left showed sub-

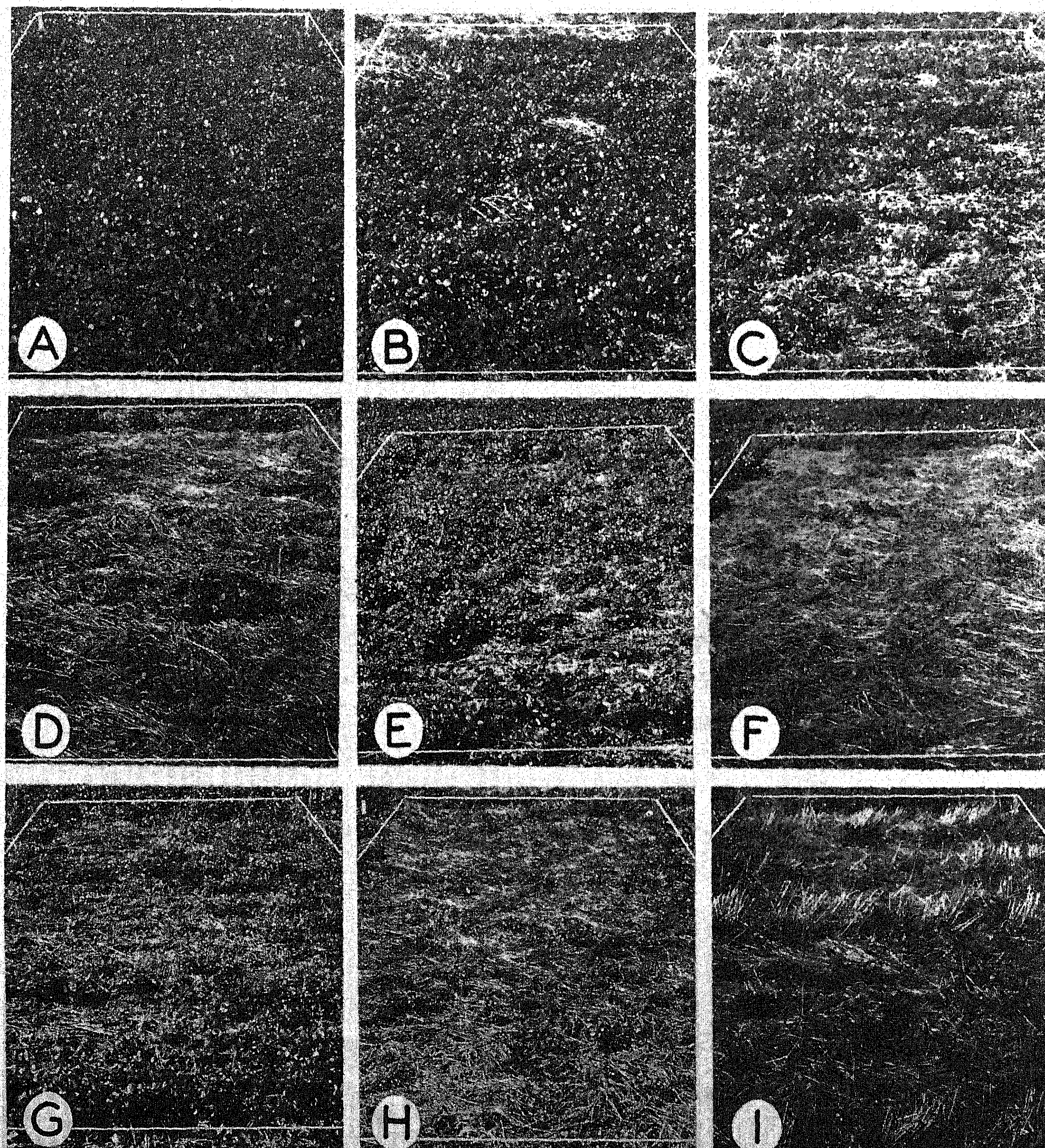

FIG. 1.—Effect of cutting red clover in the first year on stand and vigor in the second year. All plots were seeded April 23, 1952, and photographed May 19, 1953. (A) Cut Aug. 31 and clippings removed from plot. (B) Cut Aug. 31 and clippings left on plot. (C) Cut Sept. 15 and clippings removed. (D) Cut Sept. 15 and clippings left. (E) Cut Sept. 30 and clippings removed. (F) Cut Sept. 30 and clippings left. (G) Cut Oct. 15 and clippings removed. (H) Cut Oct. 15 and clippings left. (I) Check (not cut).

stantial decreases in stand. No significant stand changes were observed during the winter of 1951–1952 but large decreases occurred during the winter of 1952–53 on all plots except those cut August 31 with clippings removed (figure 1).

The 1952–53 data illustrate the importance of fall management on winter survival of first year stands. A very lush growth of clover and weeds developed on all plots during August 1952. In all cases where this growth was not removed from the plots before the onset of winter, substantial losses of stand occurred. These losses were due largely to ice sheet formation under the heavy mulch. In southern Wisconsin such mulches are a hazard to stands because they insulate the ice enabling it to persist for long periods. Mulches also increase damage from mice and diseases. Early clipping was much superior to late clipping. Plots cut Aug. 31 with the clippings removed produced the best stands. Plots cut Aug. 31 with the clippings left were not quite as good but had many more plants than plots that had not been cut or plots that were cut Sept. 15, or later. Adequate soil moisture is very important to recovery after cutting. Sufficient moisture was present in August of 1952 but not in September or October. Consequently, the plots cut in August made excellent recovery and were in good condition at the beginning of winter whereas the plots cut Sept. 15 or later made little growth after clipping and were small when the growing season ended. Many of these small plants were lost or damaged by heaving (figure 2) during late March and early April of 1953. Late clipping should not be practiced in Wisconsin.

Effect of Management on Vigor

The effects of management on vigor varied from year to year. These effects were evaluated during the year following seeding. In 1948 and 1952, plots cut the preceding Sept. 15, or later, were less vigorous and made poorer growth than those cut earlier and than those not cut in the seedling year. No differences in vigor or rate of growth were observed during 1951. In the spring of 1953, all plots except those cut Aug. 31 showed a marked reduction in vigor and very slow spring growth (figure 1). Leaving the clippings on the plots never was beneficial in any of the tests and was detrimental to the 1952–53 plots.

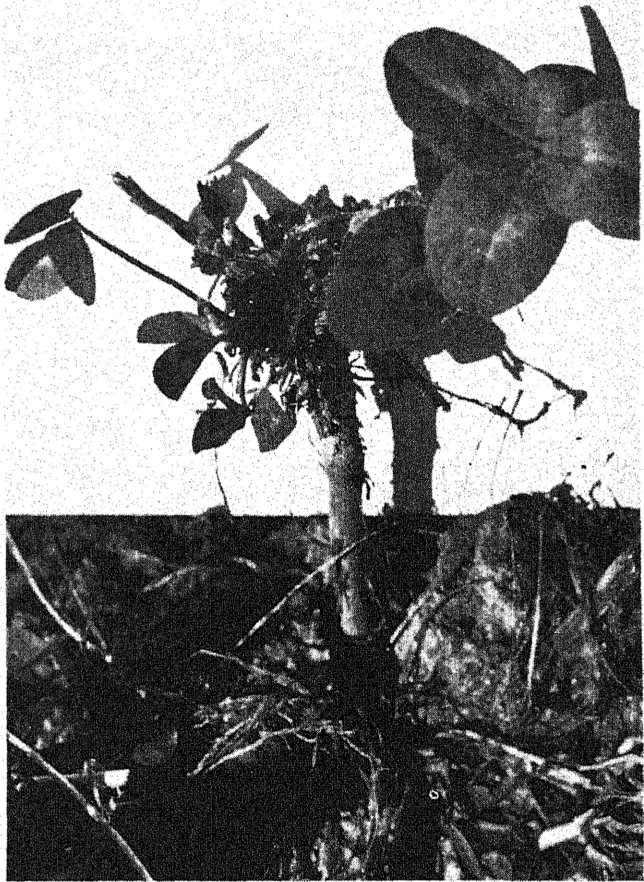

FIG. 2.—A second-year red clover plant showing the effects of heaving during the early spring of 1953, on plots that had been cut Sept. 30, 1952 and the clippings removed. Photographed May 19, 1953.

Table 3.—Tons per acre of oven-dry forage of second year red clover* following various management practices during the fall of the seedling year, at Madison, Wis.

Treatment†	Year and cutting											
	1948			1951			1952			1953		
	First	Second	Total	First	Second	Total	First	Second	Total	First	Second	Total
Not cut	1.78	0.45	2.23	2.20	1.24	3.44	1.65	0.88	2.53	0.78	0.45	1.23
Cut Aug. 31, left	—	—	—	2.36	1.19	3.55	1.69	0.86	2.55	1.60	0.89	2.49
Cut Aug. 31, removed	—	—	—	2.25	1.17	3.42	1.92	0.82	2.74	1.97	1.22	3.19
Cut Sept. 15, left	1.65	0.39	2.04	2.14	1.28	3.42	1.58	0.70	2.28	0.35	0.25	0.60
Cut Sept. 15, removed	1.59	0.30	1.89	2.27	1.23	3.60	1.58	0.76	2.34	0.87	0.40	1.27
Cut Sept. 30, left	1.66	0.37	2.03	2.35	1.19	3.54	1.43	0.62	2.05	0.40	0.31	0.71
Cut Sept. 30, removed	1.61	0.38	1.99	2.22	1.23	3.45	1.43	0.59	2.02	0.73	0.35	1.08
Cut Oct. 15, left	1.34	0.29	1.63	2.11	1.24	3.35	1.38	0.55	1.93	0.44	0.50	0.94
Cut Oct. 15, removed	1.46	0.33	1.79	2.30	1.20	3.50	1.44	0.75	2.19	0.58	.045	1.03
L.S.D. 5%	0.26	0.10	0.21	N.S.	N.S.	N.S.	0.17	N.S.	0.37	0.32	0.31	0.47
Coefficient of variation	11.0	18.8	7.3	6.7	5.1	4.2	7.4	23.6	11.1	25.2	39.5	23.3

* These data include weeds except for the second cutting of 1953 when they were removed from the clover prior to weighing. Weeds were of minor consequence except in that cutting.

† Indicates date plots were cut in the seedling year and whether clippings were left on the plots or removed.

Effect of Management on Forage Yield

The yields of oven-dry forage for the years following treatment are presented in table 3. The quantities of weeds present were small in all harvests except the second cutting of 1953. Consequently, weeds were not separated from the clover except for that cutting.

The 1948 data show that clipping on Sept. 15, or later, in the seeding year reduced yields the following summer. Greatest reductions occurred when the plots were clipped late. It made no difference in that year whether the clippings had been removed or left on the plots. No significant differences in yield were obtained in 1951. This was largely due to the extraordinarily favorable conditions for clover survival during the winter of 1950–51.

Plots clipped Aug. 31 with the clippings removed produced significantly higher yields than all other treatments for the first hay crop in 1952 and for both hay crops in 1953. It is important to point out, however, that plots clipped Sept. 30, or later, yielded significantly less forage in the first cutting of 1952 than those which were not clipped. It was concluded that clipping prior to Sept. 1 is not harmful and is sometimes beneficial but that clipping after this date is hazardous under Wisconsin conditions.

Effect of Management on Weeds

Generally, there was a highly significant negative correlation between the amount of weeds and stand of clover. Treatments that decreased stand increased the amount of weeds. This is illustrated by an analysis of the hay for the second cutting of 1953. Plots which had been clipped Aug. 31, 1952, and had the clippings removed, had excellent stands and were virtually free of weeds. Plots not clipped in the seedling year and those clipped on Sept. 15 or later had much poorer stands (table 2) and the hay from these plots contained from 1.0 to 1.2 tons of weeds per acre. More weeds were produced on plots where the first year's growth had not been removed after clipping than where it had been removed. The differences varied from 0.26 to 0.59 tons per acre depending on when the plots were clipped in the fall.

SUMMARY

The effects of cutting red clover in the fall of the seedling year on stand, vigor, and forage yield in the following year were studied at Madison, Wis. Comparisons were also made of the effects of removing and not removing the clippings from the field after cutting.

The effects of these practices varied from year to year, depending on growing conditions during the seedling year, the severity of the winters, and other factors. Clipping in late August was sometimes very beneficial and was never harmful. Cutting on Sept. 15 or later was injurious in three of four tests and never increased yields. Removing the clippings immediately after cutting reduced the amount of weeds and straw in the hay the following year and gave substantial increases in yield in some years. In general, best results were obtained when the first year's growth was clipped Aug. 31 and the clippings removed from the field.

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Effect of Topdressing Permanent Pastures With Superphosphate on Beef Yields and Distribution of Available P_2O_5 in the Soil[1]

P. C. Sandal and C. L. Garey[2]

MOST pasture soils of the humid region are deficient in available phosphate. Likewise, hundreds of soil tests in the Ozark Uplands of Arkansas, where soils range from stoney to gravelly silt loam in texture, indicate that over 75% of the soils tested are extremely low in phosphorus[3] and can be expected to respond favorably to phosphorus fertilization. The soils are generally of moderate acidity. Significant increases in beef yields during several years of annual top dressings of 20% superphosphate on permanent Bermuda-legume pastures have been reported by Sandal, *et al.* (6). To further study the relationships between the observed pasture yields as indicated by the beef yields and the probable distribution of the applied P_2O_5 in the top-soil, a study was initiated to determine the available P_2O_5 at 1-inch intervals of the pasture soils to a depth of 6 inches. Root systems of the pasture species involved generally occupy this zone. Investigations were also made to determine if any observable variation in organic matter and soil structure stability could be related to the fertilizer practices. A knowledge of the distribution, effectiveness, and availability of P_2O_5 applied annually as top dressings on permanent pastures established on soils typical of north Arkansas would aid greatly in making pasture fertilization recommendations.

Variable results concerning the penetration of phosphate into the soil following top dressings have been reported. Midgley (4) studied the penetration of phosphates and their availability on a Miami silt loam in Wisconsin and found that most of the phosphate was retained in the surface inch of soil after an interval of 6 months with the amount available increasing as the rate of application increased. Robinson and Pierre (5) studied the residual available phosphorus in three different soils from a 300-pound application of 16% superphosphate applied 11 and 7 years previously. They found large increases in available phosphorus in the surface layer of treated pasture soils, but no significant effect in the 3- to 5-inch layer. Work by Schaller (7) in 1940 indicated that in West Virginia pasture studies, phosphorus from superphosphate top dressings remained almost entirely in the surface 1½ inches with a slight penetration to 3 inches after 8 years. Brown and Munsell (1) obtained results under Connecticut conditions similar to those of Schaller.

Contrasting results from those previously mentioned are reported by Sell and Olson (8). Working with a Cecil sandy loam receiving varying rates of phosphate top-dressings, increases in available phosphorus were not found below 8 inches where less than 160 pounds P_2O_5 was applied 5 years earlier. With heavier rates, penetration of the available phosphorus was distinct in a soil depth of 12 inches. The authors concluded that with light textured soils in a high rainfall area, penetration of phosphorus is greater than in the heavy textured soils.

MATERIALS AND METHODS

Bermuda-legume pastures receiving 0, 200 and 600 pounds of 20% superphosphate per acre annually as top dressings from 1946–52 were selected in the fall of 1953 to determine the penetration of P_2O_5 in a gravelly silt loam soil. These pastures are located at the Forestry and Livestock Branch Experiment Station, Batesville, Ark. Three replicates of soil samples were taken from each pasture with ten random borings taken per replication. Each sampling per replicate was separated at 1-inch intervals in the profile from 0 to 6 inches in depth to make a composite sample of soil from each 1-inch layer of soil. The samples were analyzed in the soil testing laboratory in duplicate for percent organic matter, pH, and pounds of available P_2O_5, Ca and K per acre. The phosphate was determined by extraction with $NaHCO_3$ at pH 8.0. Physical analysis for soil structure stability was made by the wet sieving technique with a modification of 35 strokes per minute for 10 minutes (2).

RESULTS

The phosphate treatments, pounds of available P_2O_5 per acre 6 inches, and acre beef yields from 1946–52 are presented in table 1. Pastures not treated with phosphate produced an average of 61 pounds of beef per acre. In contrast, pastures topdressed annually with 200 and 600 pounds of superphosphate produced 275 and 382 pounds of beef per acre, respectively, a very significant increase.

Distribution of P_2O_5 in Soil

The average amount of available P_2O_5 per acre in the 6 inches of top-soil was found to be 11, 40 and 166 pounds, going from the check to 200 and 600 pounds of superphosphate per acre, respectively (table 1). Highly significant differences in the amounts of P_2O_5 in the soil were measured among the pastures. A significant increase is shown in the pasture receiving 600 pounds of superphosphate per acre at all depths, and in the top 2 inches for the 200-pound treatment, (figure 1). The 3- to 6-inch depths for the 200 pound treatment did not differ appreciably from each other or the check.

In the check pastures, the available P_2O_5 in the soil was very low and varied little at each 1-inch interval from the surface to the 6-inch depth. An application of 200 pounds of super per acre annually increased the pounds of available

Table 1.—Beef yields obtained from Bermuda-legume pastures and available P_2O_5 in the top 6 inches of soil resulting from annual topdressing with superphosphate at rates indicated during 1946–1952.

Rate of 20% superphosphate per acre (pounds)	Pounds available P_2O_5 per acre	Beef yield pounds per acre
0	11	61
200	40	275
600	166	382

[1] Research paper No. 1149, Journal Series, University of Arkansas, Fayetteville, Ark. Published with the permission of the Director of the Ark. Agr. Exp. Sta. Presented before Div. IX, American Society of Agronomy, St. Paul, Minn., Nov. 11, 1954. Rec. for publication Jan. 19, 1954.

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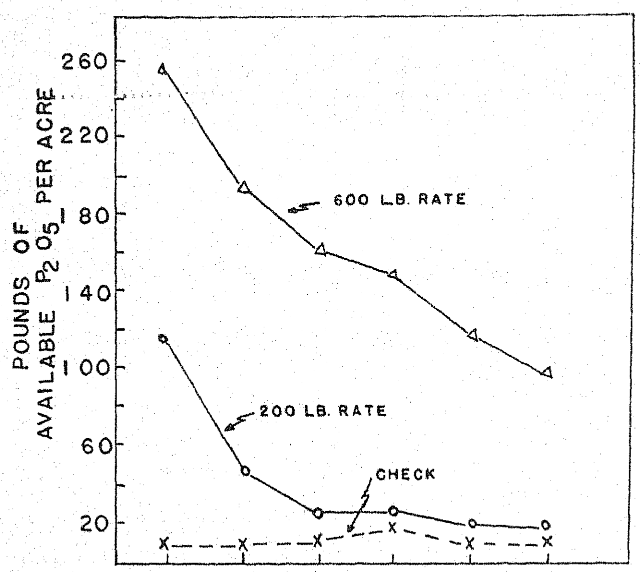

FIG. 1.—Pounds of available P_2O_5 per acre at 1-inch interval soil depths resulting from 0, 200, and 600 pound applications of 20% superphosphate per acre as annual topdressing on Bermuda-legume pasture during 1946–52.

P_2O_5 per acre to 117 in the surface inch of soil, 43 in the second inch, and 23 in the third inch of soil. The amounts of available P_2O_5 decreased some from the 3- to 6-inch level with only 17 pounds available at the 6-inch level which were little different from the measured P_2O_5 in the check pasture. These data indicate that most of the P_2O_5 applied in the superphosphate at the rate of 200 pounds per acre annually remained near the surface of the soil, yet the response in pasture growth was very good as measured by increased beef yields. Lawton (3) has shown that many plants are capable of obtaining most of their needed P_2O_5 from the top 2 or 3 inches of soil. Thus the response in beef yield from this treatment can be accounted for since the pasture species involved have a relatively extensive shallow root system which had access to adequate quantities of P_2O_5 near the surface of the soil.

When 600 pounds of super were broadcast per acre annually, a considerably increased content of P_2O_5 was found at all levels of the soil. The surface-inch contained 257 pounds of available P_2O_5 per acre with 236, 160, 147, 117, and 93 pounds available at the 2, 3, 4, 5, and 6 inch levels, respectively. Beef yields were greatly increased from this pasture receiving a heavy rate of fertilization as well as a greater depth of penetration of P_2O_5 into the soil. Although the concentration of P_2O_5 decreased with depth, the amount of available P_2O_5 at the 6-inch level was adequate to sustain vigorous plant growth. It seems apparent that the more favorable distribution of P_2O_5 in the soil encouraged a more extensive root system of the forages which enabled uptake of phosphate in a greater feeding area. This could account for the greater beef yields, a measurement of increased plant growth, from this pasture over the pasture receiving 200 pounds of superphosphate which had an accumulation of P_2O_5 resulting in a favorable root-feeding zone confined largely to the top 2 or 3 inches of soil.

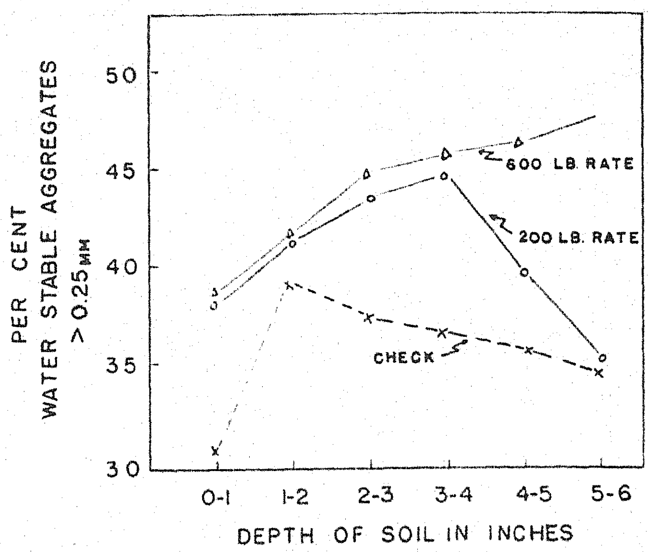

FIG. 2.—Effect of annual topdressing Bermuda-legume pastures with superphosphate upon the resulting formation of water-stable soil aggregates at 1-inch interval soil depths during 1946–52.

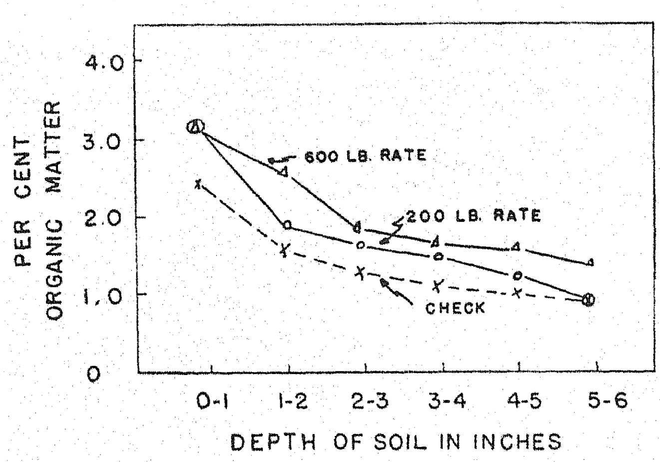

FIG. 3.—Percent organic matter at 1-inch interval soil depths resulting from 0, 200, and 600 pound applications of 20% superphosphate per acre as topdressing on Bermuda-legume pastures during 1946–52.

Soil Structure Stability

In figure 2 data are presented for the water stability of soil aggregates >0.25 mm. in diameter at each of the 6 levels of the soil on the variously phosphated pastures. On the average, the stability of soil aggregates in the 6 inches of topsoil was significantly lower in the check pasture than the two phosphated pastures, with the heavily phosphated pasture significantly superior to the pasture topdressed with 200 pounds of superphosphate per acre annually. No great differences are found at the surface among the phosphated pastures; however, the soil stability of the check pasture was decidedly lower. The lack of surface improvement may have been due to excess trampling by grazing animals since all pastures were grazed at full capacity. As the soil depth increased, an improved soil structure was evident in both phosphated pastures with the heavily phosphated pasture being the most consistent in response, increasing gradually to the depth investigated. In the check pasture, the stability of the

soil aggregates decreased with increasing depth below 2 inches. In the 200-pound applications, however, this decrease in stability did not occur until a depth of 4 inches had been reached. Here the percentage of stable aggregates decreased rapidly to the same value at 6 inches as was found in the non-treated pasture. The improved structural condition of the soil, varying among pastures, probably resulted from increased root growth and microbial activity as reflected by the organic matter content measured in the separated samples of the top soil (figure 3).

Organic Matter Distribution

The organic matter distribution data for these same pastures are presented in figure 3. Organic matter was increased at all depths of the soil almost in proportion to the amount of P_2O_5 applied. Undoubtedly this could be accounted for by the greater top- and root-growth observed in the pastures in terms of beef yields and actual root material measured. The increased growth and extension of rooting had permitted the redistribution of organic matter at higher levels with increased phosphate fertilization. The pastures having the highest organic matter content were also improved in soil structure, the latter characteristic undoubtedly being a result of organic matter and root growth and microbial activity.

The phosphated pasture soils were significantly higher in organic matter than the check pasture to a depth of 4 inches. The heavily phosphated pasture soil was significantly higher than either of the other two pastures at the 2- and 6-inch depths only. Within pastures, the organic matter in the soil varied significantly from the top inch to the 6-inch layer of soil for all three pastures.

DISCUSSION

It is felt that the data obtained under actual pasture conditions have considerable value and application to pasture fertilizer practices. Since the pasture responded to varying rates of phosphate fertilization it appears to be logical that the observed response was influenced directly by the amount and depth of P_2O_5 penetration.

The results obtained agree with the results of Sell and Olson (8) in that the concentration in the soil layers and penetration of P_2O_5 in the soil to at least 6 inches depended on the rate of P_2O_5 applied. This is in contrast to work of Midgley (4), Schaller (7) and Brown and Munsell (1) which indicated that on heavier type soils, penetration of P_2O_5 was limited to the top 2 or 3 inches of soil but concurrent with the observation that the concentration of P_2O_5 in the soil is positively related to the rates applied. Undoubtedly the gravelly silt loam soil of the Ozark Uplands in association with high rainfall and a long growing season was conducive to movement of P_2O_5 in soil by direct leaching. Redeposition of P_2O_5 in lower layers could also be accounted for by root decay with the more extensive root systems evident in the heavily phosphated pasture responsible for its greater concentration of P_2O_5 in the 6-inch soil layer.

The conclusions derived from this study show that highly productive Bermuda-legume pastures can be established and maintained by topdressing with phosphate fertilizers. No data were available to determine whether incorporation of the phosphate fertilizer in the plow layer of soil would give more highly productive pastures than topdressing. Irrespective of this lack of comparative data, it appears practical and profitable to topdress permanent pastures on lighter soils with superphosphate until such times when equipment is available which can distribute plant food in the plow layer of permanent-type pastures.

SUMMARY AND CONCLUSIONS

A study was made to determine the available P_2O_5, organic matter content, and soil structure characteristics in 1-inch layers of the top 6 inches of soil in Bermuda-legume pastures in the Ozark Uplands fertilized annually for 7 years with 0, 200 and 600 pounds of superphosphate.

Pastures topdressed annually with 0, 200, and 600 pounds of superphosphate produced 61, 275, and 382 pounds of beef per acre, respectively.

The concentration and depth of P_2O_5 movement in the soil was dependent primarily on the rate of P_2O_5 applied. Penetration of adequate amounts of P_2O_5 for plant growth did not occur below the 3-inch depth at the moderate rate of phosphate fertilization, whereas considerable penetration occurred to a depth of 6 inches under heavy fertilization. The relationship between soil type and climate in relation to phosphorus movement in the soil is discussed.

A consistently higher organic matter content and improved soil structure in the various layers of the top soil were associated with increased rates of phosphate fertilization.

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Expression of the Gene *du* in the Endosperm of Maize[1]

J. H. Davis, H. H. Kramer, and R. L. Whistler[2]

THE gene du in corn has been shown to have an important influence on the properties of the starch produced in the endosperm. Mangelsdorf (7) located du on chromosome 10 and Cameron (1) showed that it interacts with su_1 to increase the amylose or straight chain fraction of starch from approximately 25% as found in normal dent corn to 65.0% and with its allele su^{am} to increase amylose content to 50.0%.

Kramer and Whistler (6) showed that su_2, on chromosome 6, also increases amylose content, and Dvonch, *et al.* (4) and Dunn, *et al.* (3) showed that su_2 and du are additive in their effects and that the interaction of du with su also occurs in the presence of su_2. Thus it was possible to obtain 77% amylose in endosperms triply recessive for su, su_2 and du. Because of the undesirable effect of su in causing a reduction in total starch and an increase in water soluble polysaccharides, attention has been turned to a search for and a more intensive study of genes which have minor observable effects but like du may be effective in changing the composition of the starch molecule. One such important case (2) has been found but the genetic basis was not reported.

Mangelsdorf (7) noted in cultures in which du and su^{am} were segregating, that some ears gave clear-cut segregation while in others an intergradation of phenotypes made accurate classification impossible. He reported also that in some progenies du gave a distinctive dull appearance to the seeds. It is the purpose of this paper to present the results of a more detailed study of the expression of the gene du in relation to other endosperm factors.

MATERIALS AND METHODS

In 1946, seed from a selfed ear Co.43–213–1, which was indicated to be segregating Dudu, was obtained from the Maize Genetics Cooperation Center. The following year, seeds on two of four selfed ears on progeny plants could be separated into approximately 3:1 ratios for normal *vs.* opaque endosperm. In 1948 seeds from both classes were grown. Nine plants from the normal class and six from the opaque class were selfed. Three of the nine bred true for normal while the other six again segregated for normal *vs.* opaque in approximately 3:1 ratios. All six plants grown from the opaque class bred true. Seed from one selfed ear breeding true for normal and from one breeding true for opaque were used as parents in this study. Anticipating the data to be presented later, these sibling lines will be assigned genotypes Du_m (dominant dull-modifier) and $duDu_m$ respectively. Four other parents, Inbred M14, and lines homozygous for du, su^{am}, and $su^{am}du$ were used. The genotypes of the parents, seed appearance, and original sources are summarized in table 1.

In 1951, the 15 possible F_1 crosses among these 6 parents were made and in 1952, 13 of the F_1 progenies were self-pollinated and pollen used on silks of the two F_1 progenies of du × $duDu_m$ and du × Du_m, as well as on the $su^{am}du$ parent.

An additional phase of the study involved a determination of the phenotypic variation among inbred lines derived from a cross of the opaque dent parent ($duDu_m$) with the $su^{am}du$ line of Cameron (1). The cross was made in 1948 and selections made within and among selfed lines from 1949 through 1952.

Twenty-six F_1 lines were compared in 1952. Plants were selfed and used as male parents on ears of the F_1 of du × $duDu_m$ and on ears of the $su^{am}du$ parent.

EXPERIMENTAL RESULTS

F_2 and Testcross Ratios

A fairly distinct, although not always certain, classification of kernels could be made for a normal dent type, an opaque type which sometimes was accompanied by slight wrinkling, and a translucent, somewhat wrinkled phenotype as shown in figure 1. The results of classifying the F_2 seeds and the seeds on the $su^{am}du$ and F_1 testers are given in the first half of table 2. There was no observable segregation from intercrossing M14, Du_m, and su^{am}, either in F_2 or on the testers. When M14 and Du_m were used in comparable crosses with $duDu_m$ and $su^{am}du$, there were, in the F_2, consistently more normal kernels and fewer opaque kernels from the M14 crosses than from the Du_m crosses indicating that though both stocks are normal with respect to the su^{am} and du loci, the Du_m line has a modifier or modifiers which permit an opaque expression in a greater number of endosperm genotypes. A similar conclusion is apparent from comparable crosses involving the du and $duDu_m$ parents with M14, su^{am}, and $su^{am}du$. Assuming complete dominance of Du and a single dominant modifier (Du_m) to be necessary for the expression of du, 16 genotypic combinations of Du_m and su^{am} are possible in triploid maize endosperms homozygous for du. Phenotypes may be assigned to these in attempted conformance with the obtained ratios presented in table 2. The assigned genotypes and proposed phenotypes are given in table 3. From these phenotypes, expected ratios

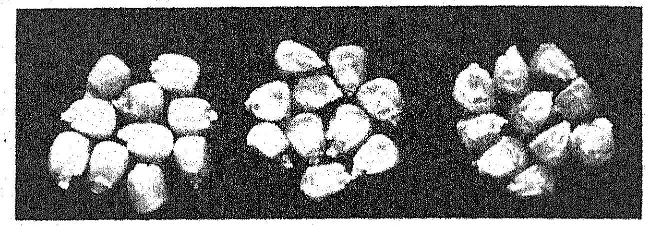

FIG. 1.—Normal starchy corn at left, opaque seeds, center, and translucent seeds, right, obtained as segregates from a cross of $su^{am}du$ × Du_m.

Table 1.—Genotype, appearance, and origin of parental lines.

1951 Culture	Genes Homozygous	Appearance of seed	Original source
169	Su Du Du_m	normal dent	Co. 43–213–1, see text
174	Su Du du_m	normal dent	Inbred M14
168	Su du Du_m	opaque dent	Co. 43–213–1, see text
159	Su du du_m	normal dent	su du, Cameron (1)* × su_2, Co. 44–19–5
165	su^{am} Du du_m	normal dent	su^{am}du, Cameron (1) × su, Co. 45–73–2
163	su^{am} du du_m	translucent	su^{am}du, Cameron (1) × su^{am}du, Co. 41–148–3

* See literature citation.

[1] Contribution from the Departments of Agronomy and Biochemistry, Purdue University, Lafayette, Ind. Journal Paper No. 830 of the Purdue University Agr. Exp. Sta. Part of a thesis submitted by the senior author in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Rec. for publication Jan. 12, 1955.

[2] Formerly graduate assistant, now Agronomist, Texas Research Foundation, Renner Tex., Professor of Genetics in Agronomy, and Assistant Head, Department of Biochemistry, respectively.

Table 2.—Observed and expected ratios of normal: opaque: translucent endosperms on ears of self-polinated F_1 plants and on ears of selected testers.

Cross No.	Cross	Observed				Expected			
		F_1 self-pollinated	(du × $duDu_m$) × F_1	(du × Du_m) × F_1	$su^{am}du$ × F_1	F_1 self-pollinated	(du × $duDu_m$) × F_1	(du × Du_m) × F_1	$su^{am}du$ × F_1
1	M14 × Du_m	All : 0: 0	All : 0:0	All : 0:0	All :0: 0	All :0:0	All :0:0	All :0:0	All :0 :0
2	M14 × su^{am}	All : 0: 0	All : 0:0	All : 0:0	All :0: 0	All :0:0	All :0:0	All :0:0	All :0 :0
3	Du_m × su^{am}	All : 0: 0	All : 0:0	All : 0:0	All :0: 0	All :0:0	All :0:0	All :0:0	All :0 :0
4	M14 × $duDu_m$	874:233: 0	129: 89:0	282: 69:0	68:0: 62	13:3:0	5:3:0	13:3:0	1:0 :1
5	Du_m × $duDu_m$	207: 79: 0	115: 95:0	302:100:0	113:0:123	3:1:0	1:1:0	3:1:0	1:0 :1
6	M14 × $su^{am}du$	646: 58: 99	204:131:0	246: 69:0	78:0:72	13:1:2	5:3:0	13:3:0	1:0 :1
7	Du_m × $su^{am}du$	841:126:150	148: 92:0	233: 58:0	101:0: 91	49:7:8	9:7:0	25:7:0	1:0 :1
8	du × M14	All : 0: 0	233: 91:0	265: 48:0	25:0: 21	All :0:0	3:1:0	7:1:0	1:0 :1
4	$duDu_m$ × M14	874:233: 0	129: 89:0	282: 69:0	68:0: 62	13:3:0	5:3:0	13:3:0:	1:0 :1
9	du × su^{am}	1141:115:181*	218:142:0	187: 57:0	76:0: 83	13:1:2	5:3:0	13:3:0	1:0 :1
10	$duDu_m$ × su^{am}	1320:217:162*	160:121:0	237: 74:0	68:0: 77	49:7:8	9:7:0	25:7:0	1:0 :1
11	du × $su^{am}du$	284: 0:297	173:186:0	211: 74:0	0:0:All	1:0:1	1:1:0	3:1:0	0:0 :All
12	$duDu_m$ × $su^{am}du$	83:434:483	68:191:0	165:145:0	0:0:All	1:7:8	1:3:0	9:7:0	0:0 :All
13	su^{am} × $su^{am}du$	552: 0:180	152:163:0	198: 78:0	66:0: 79	3:0:1	1:1:0	3:1:0	1:0 :1

* P for goodness of fit <0.05.

for each of the crosses and test crosses then were established and are presented in the last half of table 2. Chi square tests for goodness of fit of the observed ratios in table 2 to those expected showed no significant deviation for 50 of the 52 ratios. The F_2 ratios for crosses 9 and 10 which involve a comparison of du and $duDu_m$ crossed with $su^{am}du$ showed significant deviations from the 13:1:2 and 49:7:8 ratios expected. Nevertheless, the greater proportion of opaque kernels in the $duDu_m$ cross is in accord with the concept of the presence of a modifier in addition to du.

It should be pointed out that classification is more difficult on some ears than on others and although the evidence seems clear that classification for opacity due to du is enhanced by a modifier designated here as Du_m the presence of other factors which may modify the expression of du is by no means excluded. For example, Jones (5) showed that the expression of su could be altered by selection of modifying factors. Evidence for the presence of similar additional modifiers is afforded by a comparison of homozygous lines derived from a cross of $duDu_m$ × $su^{am}du$.

Variability Among Lines Homozygous for du

In 1948, when the cross of the opaque dent parent with Cameron's (1) $su^{am}du$ line was made, it was presumed that the opaque dent was du and single factor segregation for $Susu^{am}$ would be obtained. In subsequent generations, however, segregation for translucent kernels was not clear cut. Twenty-six lines were carried through F_4. The lines fell easily into two broad categories; 11 were opaque dent and 15 were translucent.

Pollen of both opaque and translucent lines, applied to the $su^{am}du$ tester line produced only wrinkled, translucent kernels showing that du was homozygous in all recovered lines.

Differences between lines within both the opaque and wrinkled group were readily apparent with respect to degree of wrinkling and shades of color, and arbitrary classes were

Table 3.—Number of doses of each of the genes su^{am} and Du_m in triploid maize endosperms homozygous for du and the phenotype assigned to each dosage combination. N = normal, O = opaque, T = translucent.

Does of Du_m	Doses of su^{am}			
	0	1	2	3
0	N	O*	T	T
1	O	O	T	T
2	O	O	T	T
3	O	O	T	T

* Cannot be distinguished from normal in some cases.

established from 1 = highly wrinkled to 9 = full dent. Table 4 presents this classification of the 26 lines in relation to the percent amylose in the endosperm starch and the segregation on the F_1 of du × $duDu_m$. Although there is variation between lines within genotypes both in degree of wrinkling and in percent amylose in the starch, there is no indication of relationship of the two characters within genotypes. The translucent lines, however, are, as a group, more wrinkled and higher in amylose than the opaque lines which is expected from the interaction of du and su^{am} shown by Cameron (1). With one exception, pollen from each of the 26 lines, applied to silks of the F_1 of du × Du_m gave a ratio of 1 normal: 1 opaque. In spite of this one significant deviation, however, a χ^2 test failed to reveal heterogeneity in segregation for the 26 lines. From the phenotypes presented in table 3, a 1:1 ratio could be obtained only if the recovered lines were homozygous for $duDu_m$. A $dudu_m$ line is expected to result in a 3:1 ratio of normal: opaque, and this ratio was realized when a du line was used as a check in the last line of table 4. Three other lines which were used as checks did not carry du and gave no observable segregation on the F_1 tester.

Expression of the Gene *du* in the Endosperm of Maize[1]

J. H. Davis, H. H. Kramer, and R. L. Whistler[2]

THE gene du in corn has been shown to have an important influence on the properties of the starch produced in the endosperm. Mangelsdorf (7) located du on chromosome 10 and Cameron (1) showed that it interacts with su_1 to increase the amylose or straight chain fraction of starch from approximately 25% as found in normal dent corn to 65.0% and with its allele su^{am} to increase amylose content to 50.0%.

Kramer and Whistler (6) showed that su_2, on chromosome 6, also increases amylose content, and Dvonch, *et al.* (4) and Dunn, *et al.* (3) showed that su_2 and du are additive in their effects and that the interaction of du with su also occurs in the presence of su_2. Thus it was possible to obtain 77% amylose in endosperms triply recessive for su, su_2 and du. Because of the undesirable effect of su in causing a reduction in total starch and an increase in water soluble polysaccharides, attention has been turned to a search for and a more intensive study of genes which have minor observable effects but like du may be effective in changing the composition of the starch molecule. One such important case (2) has been found but the genetic basis was not reported.

Mangelsdorf (7) noted in cultures in which du and su^{am} were segregating, that some ears gave clear-cut segregation while in others an intergradation of phenotypes made accurate classification impossible. He reported also that in some progenies du gave a distinctive dull appearance to the seeds. It is the purpose of this paper to present the results of a more detailed study of the expression of the gene du in relation to other endosperm factors.

MATERIALS AND METHODS

In 1946, seed from a selfed ear Co.43–213–1, which was indicated to be segregating Dudu, was obtained from the Maize Genetics Cooperation Center. The following year, seeds on two of four selfed ears on progeny plants could be separated into approximately 3:1 ratios for normal *vs.* opaque endosperm. In 1948 seeds from both classes were grown. Nine plants from the normal class and six from the opaque class were selfed. Three of the nine bred true for normal while the other six again segregated for normal *vs.* opaque in approximately 3:1 ratios. All six plants grown from the opaque class bred true. Seed from one selfed ear breeding true for normal and from one breeding true for opaque were used as parents in this study. Anticipating the data to be presented later, these sibling lines will be assigned genotypes Du_m (dominant dull-modifier) and $duDu_m$ respectively. Four other parents, Inbred M14, and lines homozygous for du, su^{am}, and $su^{am}du$ were used. The genotypes of the parents, seed appearance, and original sources are summarized in table 1.

In 1951, the 15 possible F_1 crosses among these 6 parents were made and in 1952, 13 of the F_1 progenies were self-pollinated and pollen used on silks of the two F_1 progenies of du × $duDu_m$ and du × Du_m, as well as on the $su^{am}du$ parent.

An additional phase of the study involved a determination of the phenotypic variation among inbred lines derived from a cross of the opaque dent parent ($duDu_m$) with the $su^{am}du$ line of Cameron (1). The cross was made in 1948 and selections made within and among selfed lines from 1949 through 1952. Twenty-six F_4 lines were compared in 1952. Plants were selfed and used as male parents on ears of the F_1 of du × $duDu_m$ and on ears of the $su^{am}du$ parent.

EXPERIMENTAL RESULTS

F_2 and Testcross Ratios

A fairly distinct, although not always certain, classification of kernels could be made for a normal dent type, an opaque type which sometimes was accompanied by slight wrinkling, and a translucent, somewhat wrinkled phenotype as shown in figure 1. The results of classifying the F_2 seeds and the seeds on the $su^{am}du$ and F_1 testers are given in the first half of table 2. There was no observable segregation from intercrossing M14, Du_m, and su^{am}, either in F_2 or on the testers. When M14 and Du_m were used in comparable crosses with $duDu_m$ and $su^{am}du$, there were, in the F_2, consistently more normal kernels and fewer opaque kernels from the M14 crosses than from the Du_m crosses indicating that though both stocks are normal with respect to the su^{am} and du loci, the Du_m line has a modifier or modifiers which permit an opaque expression in a greater number of endosperm genotypes. A similar conclusion is apparent from comparable crosses involving the du and $duDu_m$ parents with M14, su^{am}, and $su^{am}du$. Assuming complete dominance of Du and a single dominant modifier (Du_m) to be necessary for the expression of du, 16 genotypic combinations of Du_m and su^{am} are possible in triploid maize endosperms homozygous for du. Phenotypes may be assigned to these in attempted conformance with the obtained ratios presented in table 2. The assigned genotypes and proposed phenotypes are given in table 3. From these phenotypes, expected ratios

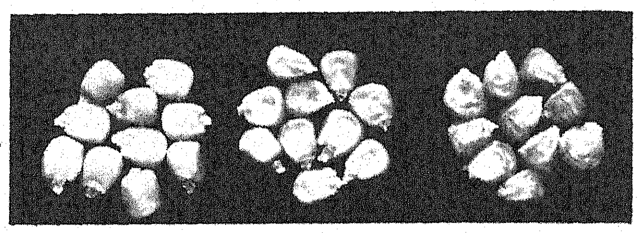

FIG. 1.—Normal starchy corn at left, opaque seeds, center, and translucent seeds, right, obtained as segregates from a cross of $su^{am}du$ × Du_m.

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174	Su Du du_m	normal dent	Inbred M14
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159	Su du du_m	normal dent	su du, Cameron (1)* × su_2, Co. 44–19–5
165	su^{am} Du du_m	normal dent	su^{am}du, Cameron (1) × su, Co. 45–73–2
163	su^{am} du du_m	translucent	su^{am}du, Cameron (1) × su^{am}du, Co. 41–148–3

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[1] Contribution from the Departments of Agronomy and Biochemistry, Purdue University, Lafayette, Ind. Journal Paper No. 830 of the Purdue University Agr. Exp. Sta. Part of a thesis submitted by the senior author in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Rec. for publication Jan. 12, 1955.

[2] Formerly graduate assistant, now Agronomist, Texas Research Foundation, Renner Tex., Professor of Genetics in Agronomy, and Assistant Head, Department of Biochemistry, respectively.

Table 2.—Observed and expected ratios of normal: opaque: translucent endosperms on ears of self-pollinated F_1 plants and on ears of selected testers.

Cross No.	Cross	Observed				Expected			
		F_1 self-pollinated	(du × $duDu_m$) × F_1	(du × Du_m) × F_1	$su^{am}du$ × F_1	F_1 self-pollinated	(du × $duDu_m$) × F_1	(du × Du_m) × F_1	$su^{am}du$ × F_1
1	M14 × Du_m	All : 0: 0	All : 0:0	All : 0:0	All :0: 0	All :0:0	All :0:0	All :0:0	All :0:0
2	M14 × su^{am}	All : 0: 0	All : 0:0	All : 0:0	All :0: 0	All :0:0	All :0:0	All :0:0	All :0:0
3	Du_m × su^{am}	All : 0: 0	All : 0:0	All : 0:0	All :0: 0	All :0:0	All :0:0	All :0:0	All :0:0
4	M14 × $duDu_m$	874:233: 0	129: 89:0	282: 69:0	68:0: 62	13:3:0	5:3:0	13:3:0	1:0:1
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9	du × su^{am}	1141:115:181*	218:142:0	187: 57:0	76:0: 83	13:1:2	5:3:0	13:3:0	1:0:1
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11	du × $su^{am}du$	284: 0:297	173:186:0	211: 74:0	0:0:All	1:0:1	1:1:0	3:1:0	0:0:All
12	$duDu_m$ × $su^{am}du$	83:434:483	68:191:0	165:145:0	0:0:All	1:7:8	1:3:0	9:7:0	0:0:All
13	su^{am} × $su^{am}du$	552: 0:180	152:163:0	198: 78:0	66:0: 79	3:0:1	1:1:0	3:1:0	1:0:1

* P for goodness of fit <0.05.

for each of the crosses and test crosses then were established and are presented in the last half of table 2. Chi square tests for goodness of fit of the observed ratios in table 2 to those expected showed no significant deviation for 50 of the 52 ratios. The F_2 ratios for crosses 9 and 10 which involve a comparison of du and $duDu_m$ crossed with $su^{am}du$ showed significant deviations from the 13:1:2 and 49:7:8 ratios expected. Nevertheless, the greater proportion of opaque kernels in the $duDu_m$ cross is in accord with the concept of the presence of a modifier in addition to du.

It should be pointed out that classification is more difficult on some ears than on others and although the evidence seems clear that classification for opacity due to du is enhanced by a modifier designated here as Du_m the presence of other factors which may modify the expression of du is by no means excluded. For example, Jones (5) showed that the expression of su could be altered by selection of modifying factors. Evidence for the presence of similar additional modifiers is afforded by a comparison of homozygous lines derived from a cross of $duDu_m$ × $su^{am}du$.

Variability Among Lines Homozygous for du

In 1948, when the cross of the opaque dent parent with Cameron's (1) $su^{am}du$ line was made, it was presumed that the opaque dent was du and single factor segregation for $Susu^{am}$ would be obtained. In subsequent generations, however, segregation for translucent kernels was not clear cut. Twenty-six lines were carried through F_4. The lines fell easily into two broad categories; 11 were opaque dent and 15 were translucent.

Pollen of both opaque and translucent lines, applied to the $su^{am}du$ tester line produced only wrinkled, translucent kernels showing that du was homozygous in all recovered lines.

Differences between lines within both the opaque and wrinkled group were readily apparent with respect to degree of wrinkling and shades of color, and arbitrary classes were

Table 3.—Number of doses of each of the genes su^{am} and Du_m in triploid maize endosperms homozygous for du and the phenotype assigned to each dosage combination. N = normal, O = opaque, T = translucent.

Does of Du_m	Doses of su^{am}			
	0	1	2	3
0	N	O*	T	T
1	O	O	T	T
2	O	O	T	T
3	O	O	T	T

* Cannot be distinguished from normal in some cases.

established from 1 = highly wrinkled to 9 = full dent. Table 4 presents this classification of the 26 lines in relation to the percent amylose in the endosperm starch and the segregation on the F_1 of du × $duDu_m$. Although there is variation between lines within genotypes both in degree of wrinkling and in percent amylose in the starch, there is no indication of relationship of the two characters within genotypes. The translucent lines, however, are, as a group, more wrinkled and higher in amylose than the opaque lines which is expected from the interaction of du and su^{am} shown by Cameron (1). With one exception, pollen from each of the 26 lines, applied to silks of the F_1 of du × Du_m gave a ratio of 1 normal: 1 opaque. In spite of this one significant deviation, however, a χ^2 test failed to reveal heterogeneity in segregation for the 26 lines. From the phenotypes presented in table 3, a 1:1 ratio could be obtained only if the recovered lines were homozygous for $duDu_m$. A $dudu_m$ line is expected to result in a 3:1 ratio of normal: opaque, and this ratio was realized when a du line was used as a check in the last line of table 4. Three other lines which were used as checks did not carry du and gave no observable segregation on the F_1 tester.

Table 4.—Degree of wrinkling of 26 homozygous lines from the cross $duDu_m \times su^{am}du$ in relation to percent amylose in the starch and segregation on a heterozygous female tester.

Degree of wrinkling*	Phenotype	Presumed genotype	No. of Lines	% Amylose in starch		Segregation on $du \times Du_m$ tester†
				Ave.	Range	
1	translucent	$su^{am}duDu_m$	1	37	—	205 : 188
2	translucent	$su^{am}duDu_m$	1	42	—	220 : 159‡
3	translucent	$su^{am}duDu_m$	2	42	38–45	424 : 413
4	translucent	$su^{am}duDu_m$	2	40	35–46	399 : 354
5	translucent	$su^{am}duDu_m$	6	46	41–50	904 : 871
6	translucent	$su^{am}duDu_m$	3	48	46–50	417 : 449
7	opaque	$SuduDu_m$	7	35	33–40	825 : 828
8	opaque	$SuduDu_m$	2	32	29–35	359 : 354
9	opaque	$SuduDu_m$	2	34	33–36	366 : 342
9	normal	$SuDuDu_m$	1	25	—	All N
9	normal	$SuDudu_m$	1	26	—	All N
9	normal	$su^{am}Dudu_m$	1	24	—	All N
9	normal	$Sududu_m$	1	—	—	129 : 47‡

* 1 = highly wrinkled, 9 = full dent.
† normal dent vs. opaque dent.
‡ $P < 0.05$ for goodness of fit to 1:1 ratio.

Dominance of Du vs. du

In order to determine whether an opaque phenotype could be obtained in endosperms with only two doses of the recessive du, two lines from table 4 presumed to be $su^{am}duDu_m$ were selected. One had been placed in class 3 and one in class 5 with respect to degree of wrinkling. Each was used as a female tester with pollen of the F_1 crosses of $su^{am} \times Du_m$ and $su^{am} \times duDu_m$. In the cross of $su^{am}duDu_m \times (su^{am} \times Du_m)$, endosperms on the female have a constant dose of 2 du and 2 or 3 doses of su^{am} and Du_m. No segregation was observed. In the cross of $su^{am}duDu_m \times (su^{am} \times duDu_m)$, endosperms have 2 or 3 doses of each of the three recessives. The segregation was in a ratio of 1 normal: 1 translucent with no opaque class being observed. It appears that du must be homozygous in order for opacity (or translucence) to be observed and Du is therefore completely dominant. Du_m and su^{am}, aside from their relationships with du appear to have no phenotypic effect on each other.

DISCUSSION

Mangelsdorf (7) and Cameron (1) in their studies with su^{am} and du, reported on the relationship of the su^{am} and su alleles with Du and du. In their studies the threshhold transition from translucence to opacity occurred with one dose of su^{am} together with one dose of Du. This genotype could fluctuate, depending on environmental conditions or modifying factors. In these studies an attempt has been made, by a study of the relationship of the Su and su^{am} alleles with Du and du, to establish a transition zone between opacity and true starchiness or the normal dent phenotype. This transition, like that of translucence to opacity is by no means clear cut. In these studies it has not been possible to differentiate the "pseudo-starchy" $su^{am}Du$ type from normal dent nor obtain classifiable segregation for Su vs. su^{am} in crosses of pseudo-starchy with normal dent.

Dunn et al. (3) have stated, and the F_2 data of cross 11 in table 2 clearly show, that one dose of Su may be substituted for su^{am} in the "amylaceous sugary" $su^{am}du$ genotype without losing the characteristic translucence of the seed. Substitution of a second dose of Su, however, results in loss of translucence and gives a genotype which may fluctuate between opacity and normal dent.

In its relationship with su^{am}, Du is completely dominant to du and the substitution of one dose of Du for one of du in the "amylaceous sugary" genotype results in a phenotype difficult to distinguish from normal dent. The incomplete dominance of Su over su^{am} and the complete dominance of Du over du combine to make the $su^{am}du$ type a sensitive female tester for Dudu segregation. On outcrossing du to normal dent stocks, lines have been recovered which cannot be differentiated from normal dent yet still give a test for dudu on the $su^{am}du$ tester. The $Sududu_m$ line used as a parent in these studies was of this type. It was compared in crosses with a du line from a segregating ear in which classification for opaque kernels could be made easily and the Du sibling line from this ear was compared in crosses with Inbred M14. The fact that both lines derived from the segregating ear gave a measurable increase in the ratio of opaque seeds as compared with their counterpart genotypes would seem to rule out the possibility of alleles at the du locus differing in effectiveness, and would favor the concept of a distinct modifier at a different locus. Since the modifier was found in progenies of stocks originally furnished to the Maize Genetics Cooperation center by Mangelsdorf, it is not surprising that he recognized the probable existence of such modifiers in ears in which completely accurate classifications were difficult.

Although Du_m appears to have little or no effect on amylose percentage, it is valuable to the extent that it facilitates phenotypic classification for du.

SUMMARY

The evidence obtained in this experiment supports the view that du, though it appears to be a completely recessive gene for opaque endosperm in maize, requires the presence of a specific modifier in order for the opaque phenotype to be consistently expressed. This modifier, arbitrarily has been given the symbol Du_m. Neither du, Du_m, nor su^{am}, acting alone, are able to produce a phenotypic effect which can be differentiated readily from normal dent; but one or more

doses of Du_{m}, and in some cases one dose of su^{am}, in the triploid maize endosperm permit the opaque expression of three doses of du. The gene Du_{m} has no phenotypic effect on su^{am} and appears to have little or no physiologic effect either alone or in combination with du or su^{am} on the amylose-amylopectin ratio in the starch.

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Notes

EFFECT OF RAW SHALE OIL NAPHTHA ON THE YIELD OF PINTO BEANS[1]

INCREASES in yields up to 125.2% have been reported by Bohmont[2] after spraying Great Northern Field Bean plants with raw shale oil naphtha. These increases, statistically significant at the 5% level, were obtained using 2 to 10 gallons per acre applied at the cotyledonary stage of development. Increased yields were thought to result from the increased number of axillary and adventitious buds which developed after treatment.

Experiments designed to test the yield response of Pinto beans, an edible dry bean, were conducted at the U. S.—Colorado Potato Field Station near Greeley, Colo., in 1953 and 1954. The 1953 experiment was a 5 by 5 Latin square; the 1954 experiment a randomized complete block replicated 5 times.

Plots were 2 rows wide and 20 feet long, separated by 2 guard rows in 1953, and by 1 guard row in 1954 to protect against drift. Plantings were made with a belt nursery planter at the rate of 60 pounds per acre. The variety Pinto U. I. 111 was used in both experiments. The raw shale oil naphtha[3] emulsified in water with G 1096 (polyoxyethylene 50 Sorbitol Hexaoleate)[4] was applied with a small hand sprayer at about 30 pounds pressure. The 1953 application was made just after the plants had unfolded their unifoliolate leaves. In 1954, the plants were sprayed when the central leaflet of the first trifoliolate leaf was about 1.5 inches long. At harvest time the plots were trimmed to 16 feet, pulled by hand, and, when dry, threshed with a Vogel experimental thresher.

Table 1.—Yield in pounds per acre of dry beans treated with several rates of raw shale oil naphtha.

Rate in gallons per acre	Yield in pounds per acre			Percent of check
	1953	1954	Mean	
0	3084	2348	2716	100
2	2971	2514	2742	101
5	2927	2550	2738	101
10	3012	2329	2671	98
15	2816	——	——	91

Yield results are reported in table 1. No significant differences were found between the treatments in either year or in the combined analysis. The coefficient of variability in each of the experiments was 8%. In both years the unifoliolate leaves wilted immediately after treatment. The trifoliolate leaves seemed to be more resistant to the spray. A definite delay in maturity was noticed in those plots receiving treatments of 10 and 15 gallons per acre in 1953. No such delay was observed in 1954.—DONALD R. WOOD, *Assistant Agronomist, Colorado Agr. Exp. Sta., Fort Collins, Colo.*

[1] Published with permission of the Director of the Colorado Agr. Exp. Sta. as Scientific Series Paper No. 455. The facilities of the U. S.–Colorado Potato Field Sta. were available under a cooperative agreement with the Bean Project, Horticultural Crops Branch, A.R.S., U.S.D.A. The writer is indebted to Jess L. Fults for encouraging this study and to Dwight Koonce, W. C. Edmundson, Jess L. Fults, Francisco Cardenas, and Roger Blouch for assistance in the field work.

[2] Bohmont, D. W. Shale oil—A new agricultural chemical. Wyo. Agr. Exp. Sta. Bul. 320. 1952.

[3] Supplied by H. M. Thorne, Shale Oil Exp. Sta., Laramie, Wyo.

[4] Supplied by the Atlas Powder Co., Wilmington, Del.

EFFECT OF CHEMICAL AND TILLAGE SUMMER FALLOW UPON WATER-INFILTRATION RATES

IN THE semi-arid farming regions it is a common practice to alternate small grains with summer fallow. The primary purpose of this program is to build up a moisture supply by subduing weed growth; it also promotes nitrification. Clean-fallowed land, however, is subject to the hazards of increased soil erosion; therefore, many farmers have turned to a stubble-mulch system. Advocates of stubble-mulch fallow contend that moisture loss and soil erosion are reduced by this system.

To date, the greatest drawback to stubble-mulch fallow has been its ineffectiveness in weed control, since the stubble is not dense enough to smother all the weeds. Several operations per season with a subsurface tillage implement are usually necessary. While considerable study has been devoted to the various methods of dryland farming, little information is available on the use of chemicals as a weed-control agent in conjunction with the stubble-mulch system. A system of chemical stubble-mulch fallow may control weeds and at the same time leave the stubble-mulch undamaged so that erosion and moisture losses would be further reduced. Since moisture conservation is foremost in a summer-fallow program, the effect of any fallow method upon water infiltration is an important consideration.

An experiment was conducted at the Sheridan Agricultural Substation in Northeastern Wyoming to determine the effect of various summer fallow upon water intake. Comparisons were established using chemical stubble-mulch fallow with no tillage treatments, clean cultivation with season-long subsurface tillage, and spring plowing followed by subsurface tillage for the remainder of the season (figure 1). The experimental plots were 1/10 acre in size, randomized and replicated. The soil may be described as a grayish-brown silt clay loam to a depth of 15 inches and a sandy clay loam below that to a depth of 60 inches. Cropping history was similar for all plots so that the main difference in infiltration rate could be attributed to the effect of varioss fallow systems being tested.

Chemical treatments consisted of Dalapon and 2,4-D ester. Dalapon was applied at the rate of 5 pounds acid per acre in early spring to control the grassy weeds. Spot treatments were made to obtain 100% grass control. 2,4-D ester was applied at the rate of ¾ pound per acre 3 times during the season for broadleaved weed control. The grassy weeds consisted mainly of foxtailgrass *(Setaria* spp.), barnyardgrass *(Echinochloa crusgalli)*, cheatgrass *(Bromus tectorum)*, and volunteer winter wheat. The broadleaved weeds were rough pigweed *(Rumex crispus)*, kochia *(Kochia scoparia)* and Russian thistle *(Salsola kali)*. The clean-cultivation method consisted of tillage with a sweep implement as frequently as necessary for good weed control. Four cultivations were made during the 1954 growing season. A third method consisted of spring plowing followed by four tillage operations during the season. Weeds were effectively controlled by all treatments.

FIG. 1.—Comparison of two methods used in handling summer fallow grounds. Let foreground, subsurface tillage fallow; center and right background, chemical stubble-mulch fallow.

Table 1.—Water-intake rate under three methods of summer fallow.*

Treatment	Rate of water intake, inches per hour		
	1st 30 Min.	2nd 30 Min.	1 Hr.
Chemical stubble-mulch fallow	2.09	0.95	1.52
Sub-surface cultivation fallow	1.59	.38	.98
Spring plow and cultivation fallow	2.12	.44	1.28
L.S.D. (0.05)	—	.44	—
(0.01)	—	.59	—

* Data represents the average of 3 replications.

A truck-mounted infiltrometer was used to determine the ability of the soil to take up water, under simulated rain of approximately 2.5 inches per hour. Where weeds in standing stubble were controlled with chemicals, the soil took in 1.52 inches in a 1-hour test compared with the plowed ground, which took in 1.28 inches per hour, and the clean-cultivated land where only a sweep machine was used, took in 0.98 inches per hour (table 1). The greatest difference in intake rate occurred during the second 30 minutes of an hour run. During this period the chemical stubble-mulch took in 0.95 inches of water. This was 216% more water than the plowed ground and 250% more water intake than the subsurface tilled plot. In another comparison in which measurements were made over a 2-hour period, the same trend continued in favor of the chemical-stubble fallow treatment.

The data presented herein are preliminary; however, the trend is clearly marked. Investigations are being continued to determine the resulting crop yields and weed-control efficiencies. However, if the data continue to be strongly in favor of the chemical-stubble system, a new economical method of land preparation for dryland farming will have been developed.—O. K. BARNES, *Superintendent, Sheridan Substation;* D. W. BOHMONT, *Head, Agronomy Department; and* FRANK RAUZI, *Soil Conservationist, ARS; Wyoming Agr. Exp. Sta., Laramie, Wyo.*

Chemicals for this experiment were furnished by The Dow Chemical Company, Midland, Mich.

A NEW INSTRUMENT FOR EMASCULATING SORGHUM[1]

AT THE Georgia Experiment Station, emasculation of sorghum *(Sorghum vulgare* Pres.) flowers with a new instrument has resulted in good seed-set. Faster emasculation with less damage to flower parts was obtained with the new instrument compared to the commonly used medium-sharp wood pencil. Use of this instrument is suggested where only small numbers of seed are required. If a large number of

[1] Jour. Series No. 279, Georgia Experiment Station, Experiment, Ga. Rec. for publication Jan. 6, 1955.

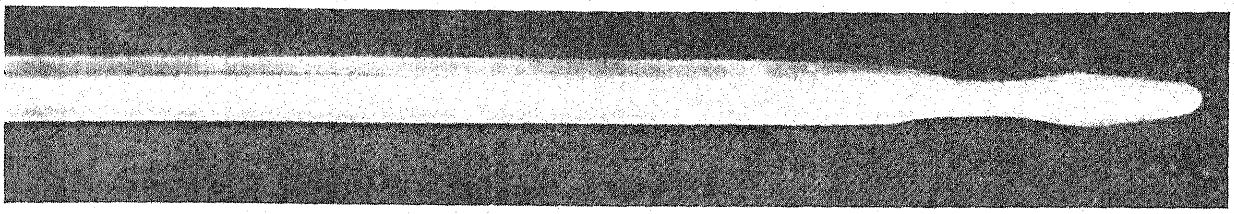


FIG. 1.—Over-all view of instrument for emasculating sorghum.

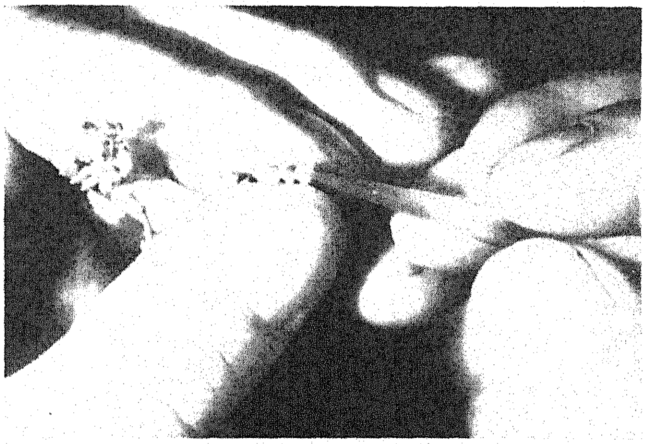


FIG. 2.—Position of the instrument in first step of emasculation process.

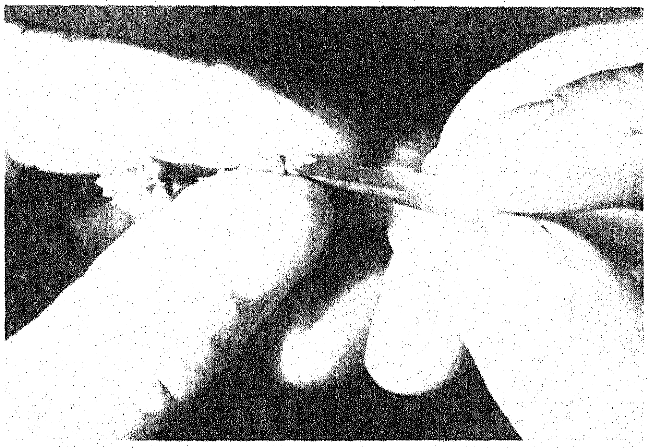


FIG. 3.—Position of the instrument in final step of emasculation process.

seeds is needed it is suggested that the method described by Stephens *et al.*[2] for mass emasculation be used.

The instrument can be easily made from plastic, close-grained wood, or other similar material. The over-all length (figure 1) is approximately 17 cm. The "Handle" is rounded to facilitate the necessary rotary movement required in emasculation, and the point is spatula-like with rounded edges just sharp enough to open the glumes with ease.

Emasculation is accomplished by opening the glumes of the spikelet (figure 2) and applying pressure at the bottom of the anthers through the palea by rotating the instrument (figure 3). The anthers immediately slip from the lemma and palea unbroken, and emasculation is completed.— H. B. HARRIS, *Assistant Agronomist, Georgia Experiment Station, Experiment, Ga.*

[2] Stephens, J. C., and Quinby, J. R. Bulk emasculation of sorghum flowers. Jour. Amer. Soc. Agron. 25:233–234. 1933.

AN EASY PULLING SOIL AUGER

SOIL and water conservation practices require know-how and much field work. Manual soil sampling is a menial task needed in soil surveys and engineering structure site borings. The pulling of a soil auger while sampling subsoils has resulted in many injuries and strained backs. Technicians in Ohio employed by the U.S.D.A. Soil Conservation Service, have designed and developed a mechanized soil auger that will eliminate some of these pulling problems, especially for the deeper samplings.

Illustrated here is the soil auger that has been mechanized by means of a simple pressure plate mounted on a left-hand threaded soil auger shaft. The stages shown in figure 1 are: left, the simple adjustment of the pressure plate to the desired depth of sampling, center, boring to the depth of the pressure plate by turning to the right, and right continued turning to the right breaks the auger loose from the ground.

The construction is such that strength, weight, and thread clogging are not problems. Standard fittings permit changing soil auger bits, and adding extension lengths for deeper borings.

There are many soils, especially those with tight subsoils, in which an auger of this type would be of value in assisting manual soil sampling work.

Specifications are as follows:
Weight—Approximately 4 lbs., 3 oz.
Length—Overall, 43 in.
Soil Auger Bit—$1\frac{1}{4}$ in. dia.—standard equipment.
Fittings—Both fittings, at the handle and at the base of the threaded shaft are standard $\frac{1}{2}$ in. threaded, male and

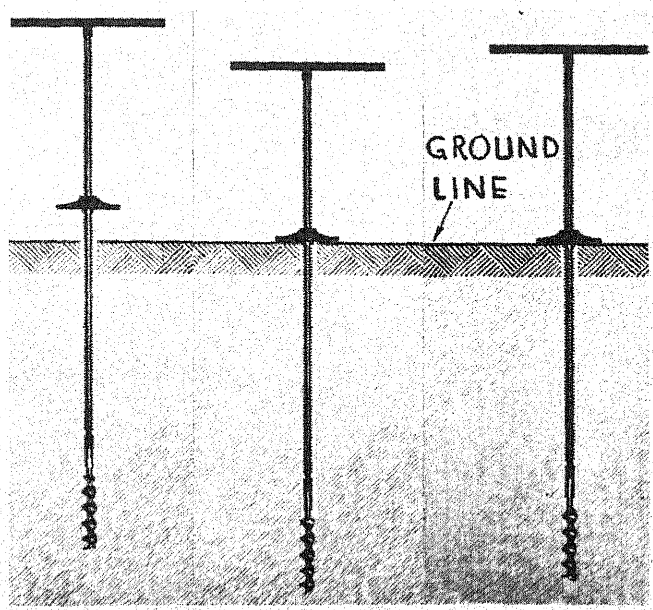


FIG. 1.—Three stages of operation of auger.

female. Adding extension lengths, and changing soil auger bits is simplified.

Extensions—Extension shafts with the above standard fittings can be added for deeper borings.

Shaft—Cold rolled steel, cadmium plated, left-hand acme thread, 33 in. overall length.

Pressure Plate—Cast aluminum, 5 in. dia., bronze insert.

Handle—Light weight tubing 12 in. long.

A patent application is being processed at this time by the United States Department of Agriculture.

The auger is available from a commercial source. Further information can be obtained from the authors.—RALPH L. MEEKER and GUY C. KEARNS, *Soil Scientist and Agricultural Engineer, respectively. U. S. Soil Conservation Service, Columbus, Ohio.*

Book Reviews

AUXINS AND PLANT GROWTH

By A. Carl Leopold. Berkeley and Los Angeles. Univ. of Calif. Press. 354 pages. illus. 1955. $5.00.

This book was written to assemble the fundamental work dealing with auxins and plant growth regulators. In the preface the author states that his object was to integrate the fundamental information on auxins with each of the applied phases of auxin technology. This aim has been attained by dividing the book into two parts: Fundamentals of Auxin Action, and Auxins in Agriculture. In the first part the development of the auxin concept and the occurrence and mechanism of growth regulators are discussed. Part two of this book deals with the practical uses of auxins in agriculture. Here are discussed such topics as rooting, parthenocarpy, flower and fruit thinning, dormancy and storage, and herbicides. The final chapter discusses the futural potential of auxins in agriculture.

The author has succeeded very well in bringing together the mass of data in this field into an effective and well illustrated treatise. Numerous photographs, graphs, charts, and diagrams are used effectively throughout the text and an extensive bibliography is included in the appendix. This book is intended primarily for research workers who are interested in both fundamental and applied phases of plant physiology. It should be of value to an agronomist, a horticulturist, a plant pathologist, as well as to the plant physiologist interested in the fundamentals of auxin physiology—S. C. WIGGANS.

APPLIED ENTOMOLOGY. AN INTRODUCTORY TEXTBOOK OF INSECTS IN THEIR RELATION TO MAN, FIFTH EDITION

By H. T. Fernald and Harold H. Shepard. New York, McGraw-Hill Book Co., 385 pp. 1955. $7.00.

Since first published in 1921 as one of the McGraw-Hill publications in the Agricultural Sciences, Applied Entomology has been a popular and useful textbook for beginning students of economic entomology. A unique feature of this book has been the presentation of subject matter according to the classification of insects. The fifth edition retains the general organization of the previous editions.

Chapters 1 to 4 deal in a general way with the place of insects in the animal kingdom, and the structure, physiology, and development of insects; chapters 5 to 8 give briefly the economic importance of insects, control methods, and a discussion of insecticides, including the new organic compounds; chapter 9 presents the system of classification; chapters 10 to 33 give a broad outline of the insect orders, including distinctive characters, family designations, examples of important species and their control; chapter 34 gives details on animals other than insects, principally mites and ticks.

The book has excellent balance between text and illustrated material, and is adequately indexed. The thorough revision of many of the chapters is evidenced by the up-to-date titles included in lists of selected references which are at the end of the chapters. A helpful innovation is the use of footnotes to indicate the pronunciation of scientific names. A more concise book is suggested by the elimination of 15 pages and 14 text figures between the editions.

The fifth edition of Applied Entomology continues to attain the objective of the authors; namely, to provide a useful and informative book for students who will not specialize in entomology, but who desire a broad general knowledge of the subject, and also to serve as an introductory survey for those students who expect to become professional entomologists.—J. T. MEDLER.

AMERICAN AGRICULTURE—ITS STRUCTURE AND PLACE IN THE ECONOMY

By Ronald L. Mighell. New York, John Wiley & Sons., Inc. 187 pp. 1955. $5.00.

This is the first of the new Census Monograph Series, sponsored by the Committee on Census Monographs of the Social Science Research Council, and written in cooperation with the USDA Agricultural Research Service. Agricultural statistics tend to make rather dull reading for almost everyone except the agricultural economist, and a book such as this might well serve to help correct such an unfortunate tendency. The voluminous agricultural facts enumerated in the 1950 census are tabled, graphed, mapped, and discussed in such a way that the general status of U. S. agriculture as of 1950, or any segment of it, is laid out clearly, simply, and impressively.

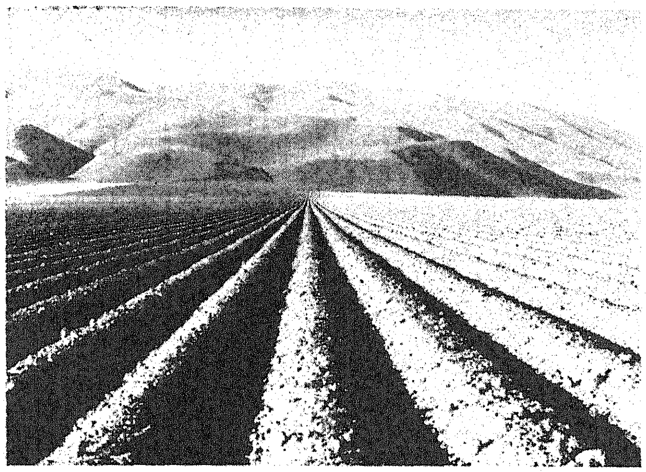
The great value of the book lies in its emphasis on historical changes that have taken place in U. S. agricultural development and the entire national economy. In the preface the author states that not even the American people themselves are fully aware of how far the nation has advanced toward an integrated economy and society in the first half of this century. Chapter headings include the following: Agriculture Today and Yesterday, which includes a discussion on the significance of new technology and inputs; Agriculture in the Total Economic Process, in which the interdependent nature of agriculture is analyzed; Dimensions of the Agricultural Plant; Structure of Commercial Farms in separate chapters on scale and type of commercial farms; Tenure and Debt; Part-time and Residential Farms; Group Interests in Agriculture—a discussion of farm organizations, co-ops, and government functions; Social Features of the Structure of Agriculture; and Changes and Structural Strain. The last is an excellent discussion of the "stresses and strains" which beset agriculture in general and individual farmers in particular. A thoughtful study of this chapter alone should lead many a reader to an understanding of the nature of contemporary agriculture and an appreciation of some of its social and economic problems. The author is an economist in Agricultural Research Service.

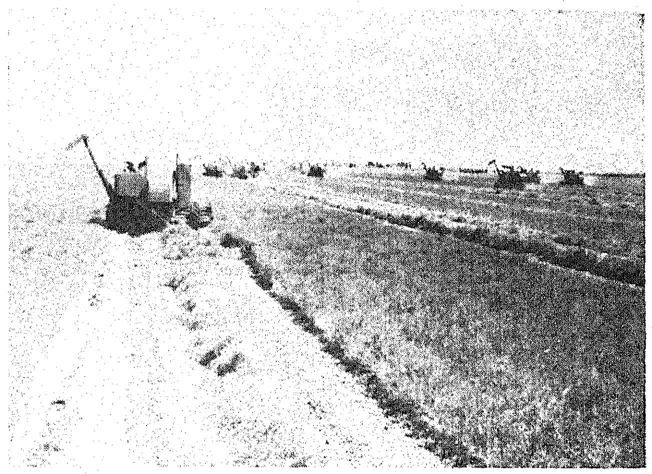
PROCEEDINGS, EIGHTH ANNUAL MEETING, SOUTHERN WEED CONFERENCE

Copies obtainable from Conference Secretary-Treasurer E. G. Rodgers, Agronomy Department, College of Agriculture, Gainesville, Fla. 477 pp., mimeo. 1955. $3.50.

This *Proceedings* contains 80 papers presented at the Eighth Annual Meeting of the Southern Weed Conference, St. Petersburg, Fla., Jan. 17–19, 1955. The papers offer an extensive summary of current work on weed control at southern research institutions. They are grouped under the following headings: general, cotton, other agronomic crops, woody plants, physiology, horticultural crops, and special weed problems. In addition, the volume contains a report of the conference's research committee and the minutes of the business meeting.

Agronomic Affairs





Typical scenes of California agriculture are the two above, left—a freshly planted sugar beet field, and right—an alfalfa field during seed harvest. These two scenes represent the extreme diversification of California agriculture. The 1955 meeting of the American Society of Agronomy will be held at the headquarters of much of California's agricultural research—the College of Agriculture campus at Davis—Aug. 15–19.

MEETINGS

June 15–17, Annual convention, American Seed Trade Assn., Minneapolis, Minn.
June 25–27, American Society of Commercial Seed Technologists, Stillwater, Okla.
June 27–29, North Central Branch, A.S.A., Iowa State College, Ames.
June 27–30, Association of Official Seed Analysts, Stillwater, Okla.
June 28–30, Pacific Northwest Regional Fertilizer Conference, Boise, Idaho.
July 7, Summer meeting, Miss. Section A.S.A. Coastal Plain Exp. Sta., Newton, Miss.
July 18–19, Eighth biennial Eastern Alfalfa Improvement Conference, Cornell University, Ithaca, N.Y.
July 27–29, Northeast Branch, American Society of Agronomy, Pennsylvania State University.
Aug. 1–6, 3rd International Congress of Biochemistry, Brussells, Belgium.
Aug. 15–19, American Society of Agronomy and Soil Science Society of America, University of California College of Agriculture, Davis.
Aug. 29–Sept. 6, International Horticultural Congress, Scheveningen, Holland.
Sept. 7–9, American Society for Horticultural Science, Michigan State University, East Lansing, Mich.

J. EARL COKE TO SPEAK AT 1955 SOCIETY MEETING

J. Earl Coke, director of the Agricultural Extension Service, University of California, and formerly Assistant Secretary of Agriculture, will be a principal speaker at the 1955 annual meeting of the American Society of Agronomy, Davis, Calif., Aug. 15–19.

Coke, according to an announcement by society president G. G. POHLMAN, will address a general meeting of the society on Aug. 15. F. N. BRIGGS of the Department of Agronomy, University of California, will speak on a program for the Crop Science Divisions of the society later in the week, with "Western Agriculture" as his topic.

The society meetings are expected to draw some 1200 members from all parts of the U. S. and from many foreign countries. In addition to special speakers on general programs, the delegates will hear more than 300 reports on recent developments in crop and soil management. Tours to points of agronomic interest in the Davis area are also being arranged for the visiting scientists.

Further details will be published in the June and July issues of the *Agronomy Journal*.

NORTH CENTRAL BRANCH SCHEDULES RESEARCH PAPERS FOR MEETING AT IOWA STATE COLLEGE IN JUNE

Plans are being made for presentation of research papers at the meeting of the North Central Branch of the American Society of Agronomy at Iowa State College, on Wednesday morning June 29. Separate sessions for crops and soils papers are being arranged, according to W. H. PIERRE, head of the Iowa State College agronomy department and 1955 chairman of the North Central Branch.

Registration for the meeting will be held from 2 to 9 p.m. on Sunday, June 26, and all day on Monday, June 27. The Monday morning program includes a welcome by Dean FLOYD ANDRE, outline of ISC agronomy department organization and program, and reports by ISC staff members.

Monday afternoon activities include the following alternative tours and discussions: plant introduction field plots; soil conditioner and ridge row corn planting experiments; turf plots, weed control studies in soybeans and corn, soil judging demonstration, and equipment and machinery display.

Tuesday morning field tours are to the small grain breeding and forage breeding nurseries. Meetings and conferences are as follows: soil physical properties and crop growth, new corn tillage practices, soil fertility experimentation, tour to corn tillage and wide row spacing plots, stand establishment tour, visit to teaching, research and soil testing laboratories, use of N^{15}, and demonstration of soil physics equipment. Afternoon activities include meetings on nitrogen research, pasture and forage evaluation, and regional soil profiles, pasture research conference, visit to seed processing plant, conference on potassium soil tests, and soil profile exhibit.

In addition to the research reports, the Wednesday morning program includes three conferences—soil moisture surveys, nitrogen soil tests and deep tillage research—a soil survey field trip, and field trips to four experimental farms.

MISSISSIPPI SECTION WILL MEET JULY 7

The Mississippi Section of the American Society of Agronomy will hold its summer meeting July 7 at the Coastal Plain Branch Experiment Station, Newton, Miss., IVAN E. MILES, president of the section, announces. Current officers of the section are MILES, president; WILLIAM L. GILES, 1st vice president; J. T. CALDWELL, JR., 2nd vice president, and C. DALE HOOVER, secretary-treasurer.

SOIL SCIENCE SOCIETY ENDORSES CHANGE IN FERTILIZER LABEL FROM OXIDE TO ELEMENTAL BASIS

In a recent mail ballot, members of the Soil Science Society of America approved a proposal to change the labeling of fertilizers from the oxide to the elemental basis. The final count, not known at this writing, was expected to be more than 95 percent in favor of the change.

If adopted by all the states, such a change would require fertilizer manufacturers and dealers to state the content of all plant nutrients in the elemental form—as is now the case with nitrogen—rather than the oxide form as now used for phosphorus, potassium, and certain other nutrient elements. The elemental basis has long been used by many foreign countries.

A complete discussion of the topic appears in the April 1955 issue of *Agronomy Journal*, pp. 191–193; and in the April 1955 issue of *Soil Science Society of America Proceedings*, pp. 247–249.

CORRECTION

Representatives of Division IV, Soil Fertility, on the board of directors of the American Society of Agronomy were incorrectly listed on page 47 of the January 1955 issue of *Agronomy Journal*. The representatives are as follows:

Past Chairman, K. C. BERGER, University of Wisconsin, Madison; and *Chairman*, W. L. NELSON, American Potash Institute, Lafayette, Ind.

ISOTOPES CONFERENCE AT MICHIGAN STATE

A conference on the Use of Isotopes in Agriculture will be held on January 12, 13, and 14, 1956 at Michigan State University, East Lansing, Mich. It will be sponsored by the Council of Participating Institutions of the Argonne National Laboratory. There will be two half-day sessions for invited papers and three half-day sessions for contributed research papers. Details concerning the submission of papers will be published later.

FREDERICK J. SALTER

FREDERICK J. SALTER, associate professor of agronomy in teaching and extension at Ohio State University from 1940 until his retirement in 1953, died of a heart ailment Feb. 9, 1955 after a short illness.

He was born in Lacrosse, Kans., Sept. 28, 1889. He received a Bachelor of Science degree from Ohio State University in 1913, Master of Science degree in 1914, and the Doctor of Philosophy degree in 1929. Dr. Salter was an instructor in agricultural chemistry at Ohio State University from 1913 to 1919, and in soils from 1924 to 1927. He was assistant professor of extension in 1925, and assistant professor of agronomy in 1929.

Dr. Salter's extension service was with the Ohio soil testing laboratory, which he initiated, and conducted almost singlehanded for a long time. As a teacher he taught the elementary soils course and a course on teaching agronomy to vocational students. He was outstandingly successful as a teacher from elementary classes to graduate students. He is beloved of many generations of Ohio State students, and will be long remembered by them for his deep personal interest in their problems, and for consultation and guidance during their academic careers.—C. J. WILLARD

LOUIS MADSEN HEADS WASHINGTON AGR. INSTITUTE

New director of the Institute of Agricultural Sciences at Washington State College is LOUIS L. MADSEN. He succeeds J. C. KNOTT, who last fall resigned as director to return to full-time teaching and research duties at WSC. As director of the Institute of Agricultural Sciences, Madsen will be in charge of all teaching, research and extension in the field of agriculture carried on by WSC.

ILLINOIS STARTS NEW PROGRAM WITH INDIA

The University of Illinois has accepted a U.S. government invitation to take part in a new India–American Inter-Institutional program through its College of Agriculture. R. W. JUGENHEIMER, professor of plant genetics and chairman of the Agriculture Subcommittee of the University's Committee on FOA Programs, and H. W. HANNAH, Associate Dean of the College of Agriculture returned from a survey trip to India on May 15.

NORTH DAKOTAN PREPARES UN WEED MANUAL

E. A. HELGESON, Chairman of the North Dakota Agricultural College botany department, is author of a comprehensive weed control manual soon to be put into use thrughout the world by technicians of the Food and Agricultural Organization of the United Nations.

The manual, containing about 70,000 words and 75 illustrations, is being published in Rome in French, Spanish, and English, and will be distributed in 70 to 80 countries. It covers chemical and cultural methods of weed control, the principles of weed control, the apparatus, chemicals to use in the tropics and in the temperate zone.

Previous work done by Dr. Helgeson for the United Nations was a six months assignment in Chile making weed control recommendations for the Chilean government.

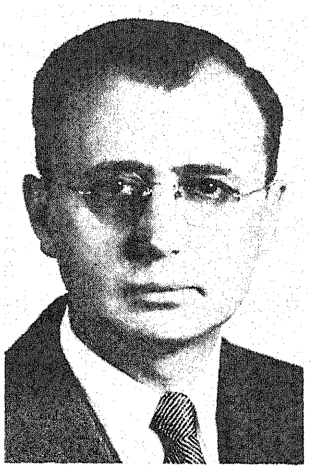
NEBRASKA HONORS T. H. GOODDING

T. H. GOODDING, professor of agronomy, was the recipient of the University of Nebraska Foundation Award for Distinguished Teaching in the physical and technological sciences. This award, which carries a stipend of $1,000 and a medal for distinguished teaching, was given to Dr. Goodding at the 27th Annual Honors Convocation. He joined the University of Nebraska staff in 1917 as an agricultural extension specialist. He received his B.S. degree from Nebraska in 1916, his M.S. from Nebraska in 1923 and the Ph.D. from Cornell University in 1933. Dr. Goodding was elected a Fellow of the American Society of Agronomy in 1947 and received the Outstanding Agronomist Award of the year from the Nebraska Crop Improvement Association in 1953. He is president of the Nebraska chapter of Sigma Xi for 1955.

E. F. FROLIK IS ASSOCIATE DIRECTOR AT NEBRASKA

ELVIN F. FROLIK has been appointed associate director of the Agricultural Experiment Stations of the University of Nebraska. Dr. Frolik is a native Nebraskan and has served as chairman of the agronomy department since 1952. He received his Bachelor's degree from the University of Nebraska in 1930, his Master's in 1932, and his Doctor's degree from the University of Minnesota in 1938. His appointment was effective April 18. Dr. Frolik initiated research on the genetic effects of atomic irradiation at Nebraska in cooperation with the Argonne National Laboratory in 1947. He succeeds M. L. BAKER, who is now in Turkey as Dean of the Nebraska delegation and chief adviser of the University's cooperative program with that country.

Dr. F. D. KEIM has been named as temporary chairman of the agronomy department.



E. F. Frolik

T. H. Goodding

THORNE IS DIRECTOR OF UTAH STATION

D. W. THORNE, vice-president of the Soil Science Society of America, has been named director of the Utah Agricultural Experi-

ment Station. In an organizational change announced April 9, the School of Agriculture, the Experiment Station and the Agricultural Extension Service at Utah were consolidated into the new Division of Agricultural Sciences. R. H. WALKER was named dean and director of the division and will continue to administer the School of Agriculture. CARL FRISCHKNECHT continues as director of Extension Service. Dr. Thorne is also in charge of all research on the USAC campus.

JOINT COMMITTEE ON FERTILIZER APPLICATION ANNOUNCES PROGRAM FOR AUG. 15 MEETING

The cooperative program of National Joint Committee on Fertilizer Application and the American Society of Agronomy will be held on Monday morning, Aug. 15 at the University of California, Davis. D. G. ALDRICH, JR., vice chairman of the committee, will preside. Papers will be presented by FRANK G. VIETS, U.S.D.A., Fort Collins, Colo.; O. A. LORENZ, University of California, Davis; D. W. HENDERSON, University of California; JAY L. HADDOCK, U.S.D.A., Logan, Utah, and STERLING A. TAYLOR, Utah State College; TOBIA GRETHER, Oxnard, Calif.; and B. A. KRANTZ, U.S.D.A., Billings, Mont.

CROP SCIENCE SOCIETY COMMITTEES

Listed below are two more committees appointed for the current year by the Crop Science Society.

MEMBERSHIP

R. P. MURPHY R. C. ECKHARDT
F. P. GARDNER J. R. COWAN
A. O. KUHN, *Chairman*

UNITS OF MEASURE FOR GRAIN AND SEED CROPS

H. C. MURPHY H. H. LAUDE
E. H. RINKE, *Chairman*

ALDERFER ON GRASSLAND STEERING COMMITTEE

The name of Dr. R. B. ALDERFER, head of the Rutgers University Soils Department, was inadvertently omitted from the Grassland Improvement Steering Committee as published in the April 1955 issue of *Agronomy Journal*.

NEWS ITEMS

PHILIP F. LOW, Purdue University Agronomist, was guest professor in soils and plant nutrition at the University of California, Berkeley, during March. Dr. Low presented five seminars from his work at Purdue on basic soil physical chemistry and participated in numerous discussions on the thermodynamics of soils.

—A—

Appointment of LARS E. EKHOLM as manager of the sales division of Climax Molybdenum Co. was announced in April by REUEL E. WARRINER, company vice president.

—A—

RICHARD C. BACK has joined Carbide and Carbon Chemicals Co., a Division of Union Carbide and Carbon Corp., as entomologist for the agricultural chemicals development group. His activities will be concerned primarily with fly repellent and insecticidal chemicals developed by Carbide.

—A—

IVAN SAMARAWIRA, Lecturer in Agricultural Botany, Faculty of Agriculture, University of Ceylon, is now at the University of Manitoba working towards his Ph.D. degree. He is working on the genetics of rust and pasmo resistance to specific collections in certain flax crosses.

—A—

HOWARD E. HEGGESTAD has recently been transferred by the USDA Agricultural Research Service, from Greeneville, Tenn., to the Plant Industry Station, Beltsville, Md. For the past 8 years Dr. Heggestad, agronomist, has been located at the Tobacco Experiment Station at Greeneville on a cooperative project between ARS and the Tennessee Agricultural Experiment Station conducting research on burley tobacco, with emphasis on breeding and disease investigations. In his present position he is research agronomist responsible for development of basic breeding stocks of all tobacco types, and disease investigations on tobacco in the Tobacco and Special Crops Section.

Rutgers University trustees have approved appointment of DR. WILLIAM E. SNYDER as professor of ornamental horticulture at the College of Agriculture. Dr. Snyder holds a similar position at Cornell University.

—A—

HAROLD H. FLOR, USDA plant pathologist at North Dakota Agricultural College has been asked by the University of Sydney, New South Wales, Australia, to serve as a foreign examiner for the Ph.D. degree.

—A—

The Plant Quarantine Service of New Mexico A & M College has announced the appointment of ROBERT M. EADS and DONALD D. LUCHT as inspectors to work on the Khapra beetle project in the state.

—A—

IVAN E. MILES, former professor of agronomy at Mississippi State College, is now serving as agronomist for the Southern District, Eastern Division, Olin Mathieson Chemical Corp., at Jackson, Miss.

—A—

W. E. LOOMIS, Professor of Plant Physiology at Iowa State College, is a visiting profesosr in Agronomy at Cornell University for the spring term. Dr. Loomis is giving a lecture series on plant growth and herbicides and is serving as consultant on the maximum yield experiment and weed control research.

—A—

WALTER L. GRIFFETH was appointed Assistant Professor in Agronomy at Cornell University Jan. 1, 1955. He received his B.S. and Ph.D. degrees at Michigan State College. He has recently been Associate Agronomist and Superintendent of the Northern Virginia Pasture Research Station. At Cornell Dr. Griffeth will be primarily responsible for developing the extension program in pastures and hay production and preservation.

COMMERCIAL NEWS

The Hypro Engineering, Inc., 700 39th Ave., N.E., Minneapolis 21, Minn., announces a sprayer pump, Model 150, for high volume spraying and rapid transfer of liquid fertilizer. Capacity of the pump is over 30 gallons per minute at tractor power take-off speed (500 RPM), yet the Model "150" has a flow rate of over 65 gallons per minute at its maximum recommended speed of 1,100 RPM. Highest suggested pressure limit is 150 pounds per square inch. It is also suitable for regular weed, insect and cattle spraying, according to the manufacturer.

—A—

A new four-page bulletin, "Properties of Molybdenum Pentachloride", is now available on request from Dept. L, Climax Molybdenum Company, 500 Fifth Avenue, New York.

Designated Bulletin Cdb-3, the publication gives the more important physical and chemical properties of chemically pure molybdenum pentachloride. It also describes the preparation of the compound.

—A—

A new row planter attachment which eliminates mixing of insecticides with fertilizer and accurately applies dry granular insecticides as you plant is announced by the E. S. Gandrud Co., Inc. of Owatonna, Minnesota. It mounts on either 2- or 4-row planters to place dry chemical insecticides with the fertilizer in the row. Designed to mount between seed cans, the attachment delivers accurately metered quantities of dry granular chemicals to the fertilizer boots through flexible metal tubes. This new Gandy attachment for row planters applies dry granular insecticides with the fertilizer as you plant to control Wireworm and Rootworms, eliminates mixing of insecticides with the fertilizer.

PERSONNEL SERVICE

The Personnel Service column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of $2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a key number which will be carried for five additional insertions unless a discontinue order is received. Items pertaining to soils positions will be inserted one time in the *Soil Science Society of America Proceedings* unless otherwise specified. The following insertions, published in earlier issues, are still available: 12–1, 1–1, 2–1, 2–2, 2–3, 4–1, 4–2, 4–3.

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Articles concerned with instruction, demonstration, experimentation, or research in agronomy will be accepted for publication from members of the Society if deemed suitable by the Editorial Board. It is understood that articles submitted for publication have not appeared previously elsewhere and that they will not be offered for simultaneous publication in other journals without the consent of the Editor of the JOURNAL. At least one author of a paper must be an active member of the American Society of Agronomy.

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AGRONOMY JOURNAL

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Resistance to Three Barley Smut Diseases in Missouri Early Beardless Strains[1]

J. M. Poehlman and C. K. Cloninger[2]

IN THE spring of 1932 C. A. Helm, Missouri Experiment Station, inspected a field of hooded winter barley growing on the C. H. E. Walther farm near Boonville, Mo. This field was earlier in maturity than other varieties of winter barley then grown in Missouri, although not uniform in this respect. Seed for this field had been purchased from a St. Louis firm, but its origin could be traced no further back than that. Since earliness is valuable in small grain crops in Missouri, Mr. Helm harvested a large number of the earliest plants and bulked the seed. Increase from this bulked seed was distributed to Missouri farmers in 1934 as a variety under the name Missouri Early Beardless (1). As might be expected in such a mass-selected variety, considerable variability in maturity and other characters still remained within Missouri Early Beardless.

In 1935, the late B. M. King assumed responsibility for the barley breeding program at the Missouri Agricultural Experiment Station. By then Missouri Early Beardless had received a favorable trial by Missouri farmers. Its earliness made it a desirable companion crop for legumes. Its hooded character was welcomed by farmers still harvesting grain with the binder. Its vigorous fall growth enhanced its usefulness for fall pasture, an important feature in the dairy sections of South Missouri where winter barley was most extensively grown. But experimental trials had demonstrated that it was less winter-hardy and lower in yield, partly as a result of its susceptibility to shattering, than such rough-awned Tennessee winter-type strains as Kentucky 1, Kentucky 2, Ward, Admire, Alaska, and others. In the breeding program, Mr. King attempted (a) to obtain more uniformity in Missouri Early Beardless by single plant selections from this mass variety, and (b) to develop "a more winter-hardy, hooded strain" by crossing Missouri Early Beardless with several of the hardy, rough-awned Tennessee winter type varieties. The crosses were made in the field in 1936.

By that time numerous lines selected from Missouri Early Beardless were being grown. Mr. King observed some of the Missouri Early Beardless selections to be free of smut, while others were heavily smutted (presumably with *Ustilago nuda*). In making the crosses Mr. King, in his words, "grabbed up a few heads" from the smut-free rows rather than use the Missouri Early Beardless variety itself. Although there had been no previous indications of smut resistance in Missouri Early Beardless, this foresight undoubtedly was responsible for the large proportion of smut resistant lines that were later selected from the progenies of these crosses.

The senior author took over the barley breeding project in 1940. In that year bulked progenies from the crosses made by Mr. King were growing in the F_5 generation. From 2 to 7 different selections from Missouri Early Beardless had been crossed with each of the Tennessee winter varieties. After the F_3 generation, these crosses had been mixed and only one bulked progeny was available for each Tennessee winter variety used originally. Several thousand selections were made from each of these bulked progenies during the F_5, F_6, and F_7 generations. One variety, Mo. B-400 from the cross Kentucky 5 × Missouri Early Beardless selection, was distributed in 1949 (3) and is now the most important variety in Missouri. A second strain, with the experimental numbers B575 (C. I. 9168) from the cross Admire × Missouri Early Beardless Selection, is being increased for possible distribution in the fall of 1955.

Resistance to Loose Smut, *Ustilago nuda*

The resistance of Missouri Early Beardless selections to loose smut, *U. nuda*, when inoculated with local collections of the smut organism has been reported by Poehlman (4,5). The resistance of Missouri Early Beardless selections, and hybrid lines with Missouri Early Beardless parentage, to a large number of collections of *U. nuda* has been reported by Cloninger and Poehlman (2). By using two Missouri Early Beardless selections (B351 and B405), one hybrid line with Missouri Early Beardless parentage (B580, Admire × Missouri Early Beardless selection), another hooded variety (North Carolina 26), and an introduction (Dohadak, C. I. 5187), Cloninger and Poehlman (2) were able to differentiate 35 collections of *U. nuda* into 13 physiologic groups on the basis of differential pathogenicity. The reaction of these five differential varieties, and the susceptible Reno check variety, to a representative collection from each of the 13 physiologic groups is presented in table 1. Varieties were considered resistant to a collection of *U. nuda* if the average infection percentage was 10% or under. Inoculations were made by the spore suspension needle method described by Poehlman (6).

The infection percentage obtained when 7 Missouri Early Beardless selections and 12 hybrid strains with Missouri Early Beardless parentage were inoculated with a

[1] Missouri College of Agriculture Journal Series Number 1497. Rec. for publication Dec. 1, 1954.

[2] Professor of Field Crops, and former Assistant Professor of Field Crops and Administrative Officer in the Office of the Dean and Director, Missouri College of Agriculture, respectively. Acknowledgment in made to Mr. Donald Terhune, former graduate student in Field Crops at the University of Missouri. Part of the data on reaction to *Ustilago nigra* and *U. hordei* has been taken from his M.S. thesis, "Resistance of Winter Barley Varieties to Three Smut Diseases." University of Missouri, 1952.

Table 1.—Reaction of six differential varieties of winter barley to each of 13 collections of *Ustilago nuda*.

Differential variety	Reaction* to collection number:												
	1	2	4	5	9	10	11	14	15	17	25	29	35
B351, Missouri Early Beardless selection	S	R	R	R	R	S	R	R	R	R	R	S	S
B405, Missouri Early Beardless selection	S	R	R	S	S	R	S	S	R	S	R	R	R
B580, Admire × Missouri Early Beardless selection	S	S	R	R	S	R	S	S	R	S	S	S	S
North Carolina Hooded 26	R	R	R	R	R	R	R	S	R	S	S	R	S
Dohadak	S	R	R	R	S	S	R	S	S	R	S	R	S
Reno (check)	S	S	S	S	S	S	S	S	S	S	S	S	S

* R = Resistant (10% infection or less).
S = Susceptible (over 10% infection).

representative collection from each of the 13 physiologic groups of *U. nuda* is reported in table 2. Resistance to several of the collections was observed in each strain except B355, B495 and Mo. B-400. Selections B351, B411, B502, B575, B635, B699, B696, B640, and B703 were resistant to most of the collections with which they were inoculated. B355 and B495, Missouri Early Beardless selections, were susceptible to all of the collections with which they were inoculated except the reaction of B355 to collection number 4. Mo. B-400 was susceptible to all of the collections with which it was inoculated. This was a surprising reaction in view of the resistance of this variety to natural infection in the field. This may indicate that field resistance in B-400 is an escape reaction.

Collection 35 is the most virulent collection of *U. nuda* tested. All of the Missouri Early Beardless selections and hybrid strains were susceptible to collection 35 except possible B405. Infection percentage in B405 when inoculated with collection 35 averaged only 6%, but the number of plants surviving each year was very small, and additional data would be desirable to confirm this reaction. Collection 35 poses a real threat to strains which derive their resistance from Missouri Early Beardless as well as to other hooded varieties of apparently similar origin, such as Hooded 16 or North Carolina 26. Collection 35 has been picked up only once—in the barley breeding nursery at Columbia in 1950.

Resistance to Semi-Loose Smut, *U. nigra*

The resistance of Missouri Early Beardless selections to semi-loose smut, *U. nigra*, has been reported by Poehlman (5). In those studies the selections were inoculated with a composite of several races. Table 3 shows the infections obtained in 9 Missouri Early Beardless selections and 6 hybrid strains with Missouri Early Beardless parentage when inoculated with each of 9 races of *U. nigra*. The 9 races of *U. nigra* were those identified by Tapke (7) from whom the original inoculum of each race was obtained. Five grams of hot-water treated seed were inoculated by the partial-vacuum technique and planted in a 5-foot row. The average number of heads of smut obtained over a 3-year period is reported here except where otherwise indicated. Two heads of smut per row, or less, is considered resistant here.

All of the Missouri Early Beardless selections except B495 exhibited a high degree of resistance to races 1, 2, 3,

Table 2.—Infection percentages* obtained in Missouri Early Beardless selections and in hybrid strains with Missouri Early Beardless parentage when inoculated with 13 collections of *Ustilago nuda*.

Variety or strain	Per cent infection with collection number:												
	1	2	4	5	9	10	11	14	15	17	25	29	35
B351, Missouri Early Beardless Selection	19	7	2	11	7	19	4	5	2	5	1	14	17
B405, Missouri Early Beardless Selection	12	4	9	16	47	4	45	16	1	56	1	5	6
B411, Missouri Early Beardless Selection	0	2	0	0	1	0	0	—	—	0	—	—	56
B502, Missouri Early Beardless Selection	16	1	1	0	1	0	—	—	—	0	—	—	—
B538, Missouri Early Beardless Selection	45	2	21	7	1	1	—	—	—	0	—	—	—
B355, Missouri Early Beardless Selection	45	39	9	76	13	54	—	—	—	—	—	15	—
B495, Missouri Early Beardless Selection	—	12	—	—	25	—	—	—	—	25	—	—	12
B575, Admire × Missouri Early Beardless Selection	2	1	4	1	1	0	2	—	—	0	7	—	48
B580, Admire × Missouri Early Beardless Selection	21	14	6	8	48	9	60	13	2	69	16	18	26
B588, Admire × Missouri Early Beardless Selection	11	5	9	2	29	2	—	—	—	90	—	—	—
B631, Admire × Missouri Early Beardless Selection	15	8	9	24	44	17	—	—	—	57	—	—	—
B635, Admire × Missouri Early Beardless Selection	2	1	9	0	35	6	—	—	—	56	—	—	—
B698, Admire × Missouri Early Beardless Selection	3	4	4	2	5	1	—	—	—	0	—	—	—
B699, Admire × Missouri Early Beardless Selection	3	11	1	16	4	2	30	—	—	1	51	—	51
B696, Kentucky 2 × Missouri Early Beardless Selection	13	4	2	7	0	0	10	—	—	0	8	—	74
B640, Ward × Missouri Early Beardless Selection	0	8	3	0	1	0	24	—	—	4	21	—	77
B703, B289 × Missouri Early Beardless Selection	3	9	2	6	6	13	13	—	—	10	0	—	40
B705, Kentucky 5 × Missouri Early Beardless Selection	—	26	—	—	—	—	34	—	—	—	50	—	17
Mo. B-400 (Kentucky 5 × Missouri Early Beardless Selection)	30	20	53	30	52	23	73	28	21	92	22	—	—
Hooded 16 (check)	5	2	2	2	1	1	0	2	1	1	0	0	46
North Carolina 26 (check)	1	1	5	6	1	1	1	13	9	15	14	2	34
Reno (check)	55	63	70	47	63	44	46	48	24	62	41	59	53

* Infection percentages reported are averages of 2 to 5 years data.

Table 3.—Reaction of 9 Missouri Early Beardless selections and 6 hybrid strains with Missouri Early Beardless parentage to 9 physiologic races of *Ustilago nigra.*

Variety or strain	Number of smutted heads* when inoculated with *U. nigra* race:								
	1	2	3	4	5	6	7	8	9
Selections and hybrid strains resistant to races 1, 2, 3, and 4:									
B351 Missouri Early Beardless Selection	4	0	0.3	1	7	4	14	3	11
B404 Missouri Early Beardless Selection	1	2	0.3	0.3	10	12	22	5	24
B411 Missouri Early Beardless Selection	0	0	0	0	8	4	4	1	3
B472 Missouri Early Beardless Selection	2	0	0.3	0	16	7	11	5	17
B502 Missouri Early Beardless Selection	0	0	0	0	22	6	7	5	23
B507 Missouri Early Beardless Selection	0	0.6	0.3	12	10	5	15	2	8
B538 Missouri Early Beardless Selection	0	0.3	0.6	1	10	2	7	6	13
B539 Missouri Early Beardless Selection	0.3	1	2	3	10	3	13	6	13
B575 Admire × Missouri Early Beardless Selection	0	0	0.3	0.3	4	5	10	7	8
B699†Admire × Missouri Early Beardless Selection	0	0	0	0	17	13	30	18	24
B696‡ Kentucky 2 × Missouri Early Beardless Selection	0.5	0	0.5	0	3	2	14	2	8
B700‡ Alaska × Missouri Early Beardless Selection	0	0	0.5	0	6	4	11	8	12
B703‡ B289 × Missouri Early Beardless Selection	0	4	5	2	13	6	15	11	23
Susceptible Strains:									
B495 Missouri Early Beardless Selection	42	47	27	17	26	6	23	18	61
Mo. B-400‡ (Kentucky 5 × Missouri Early Beardless Selection)	28	16	39	13	8	2	16	28	24

* Number of smutted heads in a 5-foot row which had been planted with 5 g. of inoculated seed. Results are averaged for a 3-year period except where indicated otherwise. Two heads smut per row, or less, is considered resistant here.
† One year's data only.
‡ Two years' data only.

Table 4.—Reaction of Missouri Early Beardless selections and hybrid strains with Missouri Early Beardless parentage to 13 physiologic races of *Ustilago hordei.*

Variety or strain	Number of smutted heads* when inoculated with *U. hordei* race												
	1	2	3	4	5	6	7	8	9	10	11	12	13
B355 Missouri Early Beardless Selection	0	0	0	0	4	8	5	0.6	2	0	0.3	4	4
B637 Michigan Winter × Missouri Early Beardless Selection	0	0	2	0	0.6	0.6	0	0.6	0.6	0	0	0.3	0
B696† Kentucky 2 × Missouri Early Beardless Selection	2	1	3	2	0	1	6	3	13	1	4	5	1
B351 Missouri Early Beardless Selection	1	0	1	4	0.6	2	10	0.6	14	6	2	6	3
B404 Missouri Early Beardless Selection	0	0.3	3	6	1	3	10	3	25	17	1	16	1
B411 Missouri Early Beardless Selection	0	0	9	5	0	0	6	0	10	3	1	14	8
B472 Missouri Early Beardless Selection	0	0	2	3	0	0.3	14	0	16	9	3	8	3
B502 Missouri Early Beardless Selection	0	0	0.6	3	0	0	7	0.3	18	9	1	11	0
B507 Missouri Early Beardless Selection	0.3	1	2	2	0	0	7	0	14	10	2	14	0.3
B538 Missouri Early Beardless Selection	1	2	2	3	0	2	12	3	14	5	0.6	15	2
B539 Missouri Early Beardless Selection	0.3	0	3	5	0.3	1	10	0.3	14	4	6	12	0.6
B700‡ Alaska × Missouri Early Beardless Selection	0	0	0	4	0	0	12	0	13	12	0	13	0
B495 Missouri Early Beardless Selection	7	1	3	9	22	39	32	39	25	16	18	40	1
Mo. B-400‡ Kentucky 5 × Missouri Early Beardless Selection	0	0	7	4	12	23	23	19	30	26	15	13	0

* Number of smutted heads in a 5-foot row which had been planted with 5 g. of inoculated seed. Results are average for a 3-year period except where indicated otherwise. Two smutted heads per row, or less, is considered resistant here.
† Two years' data only.
‡ One year's data only.

and 4, but were mostly susceptible to races 5, 6, 7, 8, and 9. Heaviest infections were obtained with collections 5, 7, and 9. The hybrid strains with Missouri Early Beardless parentage, with the exception of Mo. B-400, showed the same reaction pattern, being generally resistant to races 1 to 4 and mostly susceptible to races 5 to 9. Missouri Early Beardless Selection, B495, was susceptible to all races of *U. nigra.* Mo. B-400 was susceptible to all races except possibly race 6.

Resistance to Covered Smut, *U. hordei*

Resistance to covered smut, *U. hordei,* has been reported in Missouri Early Beardless selections by Poehlman (5). A composite of races was used in that study. Infection varied from 1 to 14 heads per 5-foot row. The infection obtained when 10 Missouri Early Beardless selections and 5 hybrid strains with Missouri Early Beardless parentage were inoculated with each of 13 races of *U. hordei* is reported in table 4. The 13 races used were those described by Tapke (8) who supplied the original inoculum. As with the *U. nigra* studies, a 5-g. sample was inoculated by the partial vacuum technique and planted in a 5-foot row. Infection is reported as the average number of smutted heads per 5-foot row for a 3-year period unless noted otherwise. Varieties are considered resistant here if infection did not exceed 2 heads per row.

One Missouri Early Beardless strain, B355, was resistant to races 1, 2, 3, 4, 8, 9, 10, and 11. One hybrid strain, B637 Michigan Winter × Missouri Early Beardless Selec-

tion, was resistant to all 13 races. Another hybrid strain, B696 Kentucky 2 × Missouri Early Beardless Selection, was resistant to races 1, 2, 4, 5, 6, 10, and 13. Missouri Early Beardless selection, B495, was susceptible to all races except 2 and 13. Mo. B-400 was susceptible to all races except 1, 2, and 13. The remaining Missouri Early Beardless selections and hybrid strains exhibited a high degree of resistance to races 1, 2, 3, 5, 6, 8, 11, and 13. Races 9 and 12 were the most virulent as measured by the amount of infection in susceptible varieties.

The susceptible reaction exhibited in the Mo. B-400 variety is of interest because the incidence of covered smut has gradually increased in this variety in the field, as well as other commercial varieties growing in Missouri, since 1952. Strain B575, Admire × Missouri Early Beardless, which is being increased for distribution and which may replace much of the Mo. B-400 variety in Missouri, has not been tested with individual races of *U. hordei*. In 1954 no smutted heads were observed in a 10-foot row of B575 which had been planted with seed inoculated with an unknown race of covered smut collected in Missouri. A similarly inoculated row of Mo. B-400 produced 25 smutted heads.

SUMMARY

Two Missouri Early Beardless selections, and one hybrid line with Missouri Early Beardless parentage, along with another hooded winter variety and an introduction, have been used as differentials to classify 35 collections of *U. nuda* into 13 physiologic groups on the basis of differential pathogenicity. Other winter barley strains with Missouri Early Beardless origin vary in their reaction to representative collections of each of these 13 physiologic groups of *U. nuda*. One collection infects all Missouri Early Beardless strains, with one possible exception. Several strains of Missouri Early Beardless origin are resistant to 4 of the 7 physiologic races of *U. nigra* and several strains are resistant to 8 of the 13 physiologic races of *U. hordei*. One hybrid strain is resistant to all races of *U. hordei*.

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Responses of White Pea Beans to Various Humidities and Temperatures of Storage[1]

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MICHIGAN is the leading producer of white pea beans for commercial canning. The crop is harvested and stored at a moisture content higher than ordinarily considered practicable in order to avoid slow, uneven soaking and cooking, and to avoid split beans, which are worthless for canning.

As a result of the necessary and accepted practice of storing the crop at moisture contents of approximately 17 or 18%, considerable difficulty is encountered in storage, particularly when the beans cannot be moved in bulk from bin to bin. When beans are stored in 100 pound sacks, excessive rancidity, heating, and molding occur.

The present study was initiated in an attempt to learn certain fundamental facts in regard to the behavior of beans when stored in air at various relative humidities and temperatures.

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LITERATURE REVIEW

Numerous articles have been published concerning the conditions necessary for safe storage of farm products. A recent monograph (1) by the American Association of Cereal Chemists lists hundreds of papers, that are pertinent to the problem. For many years, a more or less standard approach has been that of storing the product in question at a constant relative humidity (2, 4, 13), until an essentially constant weight is reached. Analysis for moisture content then gives the equilibrium moisture content for that relative humidity (and temperature) and indirectly gives the vapor pressure of the sample. Further examination of the sample for molds (10, 11), rate of respiration (6), temperature rise (11), changes in chemical composition (1), discoloration (9), viability (3), etc., gives a clear indication of how such a sample will behave when stored at any vapor pressure and temperature, or at any given moisture content. In general, mycelial growth of molds will occur at a somewhat lower moisture content than will sporulation (1). Molds vary considerably (1, 11) in their requirements for growth. However, little molding may be expected at relative humidities less than 75% in moderately long storage (1, 11). Some materials will support mold growth in slightly drier atmospheres than will other materials (1, 5). During the preparation of this manuscript, a paper has appeared on the hygroscopic characteristcs of white pea beans (12).

EXPERIMENTAL PROCEDURE

Two lots of beans, one "dry" (about 14% moisture) and one "wet" (about 20% moisture), were used to assure uniform sub-

Table 1.—A sample of "wet" and a sample of "dry" beans were placed at each of the relative humidities and temperatures shown in the table, and, with occasional weighings, were left until they had attained constant weight. The percentage moisture in these beans was determined by loss in vacuum in 44 hrs. at 100° F.

Sample R.H.%	Percentage moisture at equilibrium at the temperature, F.° shown								
	40°	50°	70°	80°	90°	100°	(first) 110°	(second) 110°	130°
55 wet	12.69	12.94	12.21	11.77	11.53	11.25	11.40	11.19	11.71
55 dry	11.49	12.91	12.44	11.87	11.70	11.15	11.40	10.99	11.61
55 average	12.09	12.92	12.32	11.82	11.61	11.20	11.40	11.09	11.66
65 wet	14.08	14.50	13.96	13.56	13.34	12.88	12.57	12.80	12.30*
65 dry	13.11	14.19	14.02	13.64	13.48	12.66	12.54	12.88	13.16*
65 average	13.60	14.34	13.99	13.60	13.41	12.77	12.55	12.84	13.23
70 wet	14.73	15.52	15.27	14.49	14.37	14.27	14.73	13.76	14.42*
70 dry	14.02	15.14	15.21	14.47	14.37	14.10	14.39	13.61	14.26*
70 average	14.38	15.33	15.24	14.48	14.37	14.19	14.56	13.68	14.34
75 wet		16.53	16.28	15.68	15.34	15.76	15.44*	16.01*	15.97†
75 dry	Lost	16.22	16.30	15.56	15.30	15.76	15.57	15.66*	16.11†
75 average		16.37	16.29	15.62	15.32	15.76	15.50	15.83	16.04
80 wet	17.10	18.23	17.98	16.81		17.16*	16.58†	17.40*	
80 dry	16.89	18.03	17.69	16.83	Lost	17.07	16.46*	17.42*	Lost
80 average	17.00	18.13	17.83	16.82		17.11	16.52	17.41	
85 wet	19.08	19.59	19.47	18.06	17.84	19.32*	19.44†	19.48*	20.70†
85 dry	19.16	19.56	19.31	18.02	17.94	19.33*	19.11*	20.17*	21.57†
85 average	19.12	19.57	19.39	18.04	17.89	19.32	19.27	19.82	21.14

* Discolored.
† Discolored badly.

samples. These were stored at a sub-zero temperature to prevent molding and insect damage. Quart containers were prepared, in which various relative humidities (55, 65, 70, 75, 80 and 85%) were maintained by use of suitable concentrations of sulphuric acid (13). Two weighed samples of 100 beans each, one sample "dry" and the other "wet", were placed in cheesecloth bags and suspended in the air above the acid.

Periodic weighings showed when equilibrium had been reached. This procedure was repeated in constant temperature chambers at 40°, 50°, 70°, 80°, 90°, 100°, 110°, and 130°F. After equilibrium was reached, a portion of each sample was used for the determination of moisture content, by loss of weight in 44 hours in a vacuum oven at 100°C. A 5-g. sample was used to determine the mold spore population. The beans were washed in 10 ml. of water to remove the spores. Five dilutions of this spore suspension were made and plated on a medium composed of 2% plain malt extract, 1% sodium chloride and 2% agar. Counts of mold colonies were made after 5 days incubation and are expressed in colonies per gram of beans.

EXPERIMENTAL RESULTS

Table 1 shows the moisture contents of the beans at equilibrium with air at various temperatures and relative humidities. In each case, the values for the samples originally "dry" and "wet" are given, as well as the average of the two values. The duration of the exposures at the various temperatures is shown in table 2.

Two lots were run at the various relative humidities at 110°F. In the first run, it was observed that considerable darkening of the beans was occurring especially at the higher relative humidities, and it seemed difficult to obtain a constant equilibrium weight. The moisture contents appeared to be giving an inversion in the moisture curves. It was felt that the discoloring might be related to these matters. For this reason, samples from another lot of "dry" beans were obtained, and the 110°F. series was repeated. In this second case, the samples were removed when equilibrium was almost established, but before the discoloring

Table 2.—The duration of exposure at the various temperatures is shown.

Sample	Temp.	Start	Finish	Approx. days duration
		First lot of beans		
1	90°F.	Nov. 7, 1952	Dec. 8, 1952	30
2	80°F.	Dec. 12, 1952	Feb. 1, 1953	50
3	70°F.	Feb. 3, 1953	Mar. 20, 1953	45
4	50°F.	Mar. 4, 1953	Aug. 8, 1953	155
5	110°F. (First)	Aug. 19, 1953	Nov. 9, 1953	80
		Second lot of beans		
6	110°F.	Nov. 13, 1953	Dec. 1, 1953	20
7	100°F.	Dec. 4, 1953	Dec. 28, 1953	24
8	130°F.	Jan. 8, 1954	Jan. 20, 1954	12
9	40°F.	Jan. 31, 1954	June 2, 1954	122
10	90°F.	Feb. 25, 1954	April 5, 1954	40

was extreme. The moisture values show that much the same relationships of moisture content developed in both cases. The discoloration, although not so extreme, was still very noticeable, and greater than at the lower temperatures.

Figure 1 shows the degree of discoloration that occurred in the beans stored at the various relative humidities and temperatures. Beans stored at higher relative humidities were darkened. At 130°F. and 85% R.H. the cotyledons were chocolate-brown in color, while at the other extreme of temperature and relative humidity the color was almost white. Figure 2 shows the difference in appearance of beans stored 20 to 80 days respectively at 110°F. and at various relative humidities. At high relative humidities and with long storage, pronounced browning of the cotyledons occurred.

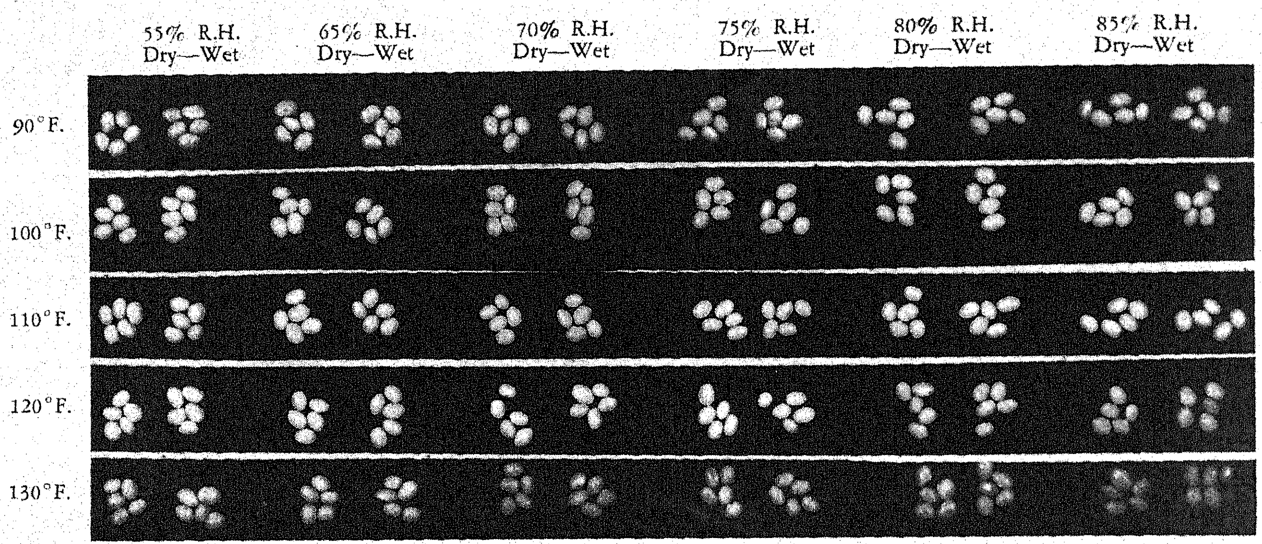

FIG. 1.—Two lots of beans, "Dry" (14%) and "Wet" (20%) were stored at the temperatures and relative humidities shown until they reached constant weight. Note the very much discolored beans at the higher relative humidities and temperatures, especially 110° and 130°F.

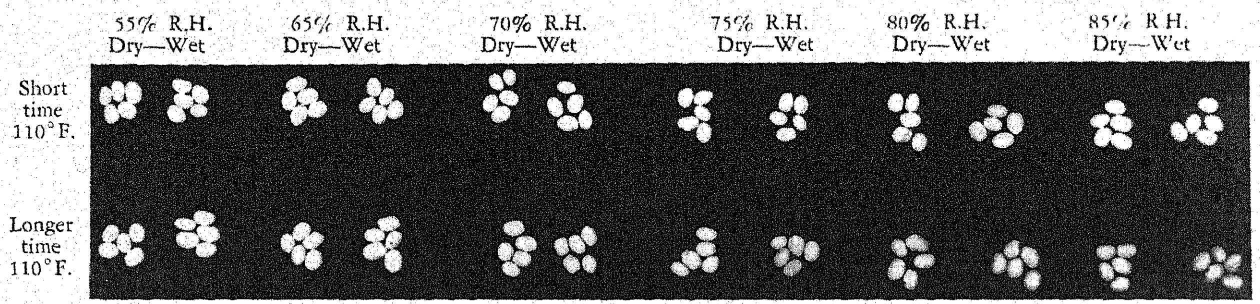

FIG. 2.—When the beans were stored for a longer time at 110°F., the discoloration increased.

Figure 3 shows the data of table 1, graphically, in terms of temperature, while figure 4 shows them in terms of relative humidity. For the four temperatures, 50°, 70°, 80°, and 90°F., the moisture curves were entirely regular and virtually parallel, with a higher moisture content being found in every case at the lower temperature. At 40°F., moisture contents were uniformly lower than at 50°F. Throughout the 110° and 130°F. series the moisture contents were somewhat above what would have been expected on the basis of results obtained in the 50° to 90°F. series. At the higher relative humidities the moisture contents were far higher in the 100°, 110°, and 130°F. series than in the 80° or 90°F. series. Associated with the higher moisture contents at higher temperatures, a decided discoloration and a strongly rancid odor were found. The mold studies (table 3) showed that molds were not responsible for this discoloration since the beans at 130°F. had no molds, and those at 110°F. had few. Discoloration of the cotyledons was much greater than was ordinarily visible, since the seedcoats were discolored only partially, mainly around the micropyle.

Figure 5 shows the curves for the establishment of constant weight of samples of beans at various representative temperatures and relative humidities. Establishment of a constant weight at the lower temperatures was slower than at the higher temperatures. In several of the curves, the evidence is plain that the sulfuric acid solutions were not maintaining strictly constant relative humidities for the first few days. This was particularly noticeable when the effects of the two samples were not more or less off-setting, i.e., one sample taking up moisture and the other losing it. One such curve, 80°F., 85% R.H., with wet seed is shown (figure 5). In this and similar cases, both samples tended to take up moisture from the air. However, during the earlier period, this wet sample actually lost a small amount of water to the atmosphere, which was evidently not precisely at 85% relative humidity, because of the presence of the "dry" sample, which was absorbing water from the atmosphere rather rapidly. The necessity for using comparatively small samples of beans and large volumes and surfaces of solution is evident. Whenever the samples could be arranged to counteract each other, smoother curves were obtained.

DISCUSSION

The "equilibrium-moisture-content" approach to the problem of storage of various crops has often been used in agronomic and biochemical research. Nevertheless, data concerning the effects of temperatures on these equilibria are comparatively scarce (3, 7), and information concerning white pea beans at various temperatures and relative humidities seems unavailable. Yet, in the case of beans, the problem is a particularly pertinent and troublesome one.

Table 3.—Average mold count per gram of beans stored at different relative humidities and temperatures until constant weight was attained.

R.H.	Temperature								
	40°	50°	70°	80°	90°	100°	110°	110°	130°
					Dry beans (at start)				
55	24	24	14	16	24	948	8	0	0
65	36	0	4	4	36	228	0	0	0
70	6	4	2	2	6	94	36	0	0
75	0	0	11	4	0	0	74,344	12	0
80	2	4	11	11	2	24	0	4	0
85	0	0	34	0	0	284,800	0	0	4
					Wet beans (at start)				
55	20	68	100	14	70	420	4	122	0
65	28	40	164	3	14	232	8	4	0
70	36	28	80	14	58	106	4	32	0
75	4	0	51	0	2	0	0	4	0
80	40	12	17	350	40	4,260	0	0	0
85	8	12	404	97,533	4	3,382,000	0	4	0

Beans are harvested in the fall and stored in a rather damp condition in cool, unheated warehouses. They are often subject to a considerable rise in temperature before they are processed. When it is necessary to hold these beans in storage during the following hot summer months, the problem is magnified. Not only does the temperature become more favorable for mold growth, but the relative humidity of the air spaces between the beans increases, thus favoring spoilage.

As a specific example, to show the applicability of these values to storage practice, let us assume that a sample of

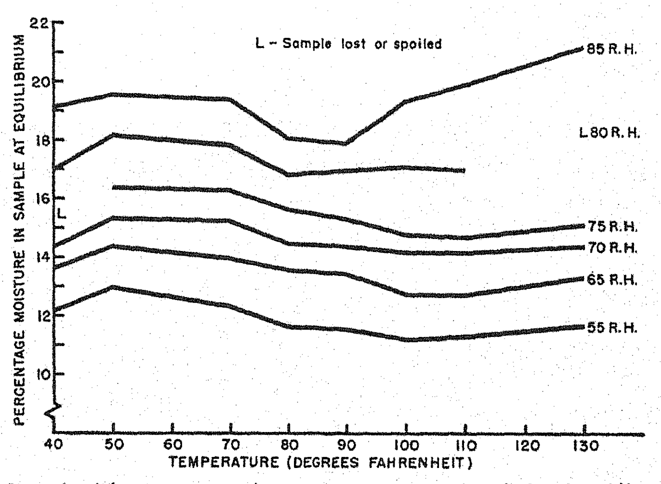

FIG. 4.—The average moisture contents at each relative humidity and temperature (table 1) are shown in the curves to show the change in moisture content as the temperature changed at various fixed relative humidities.

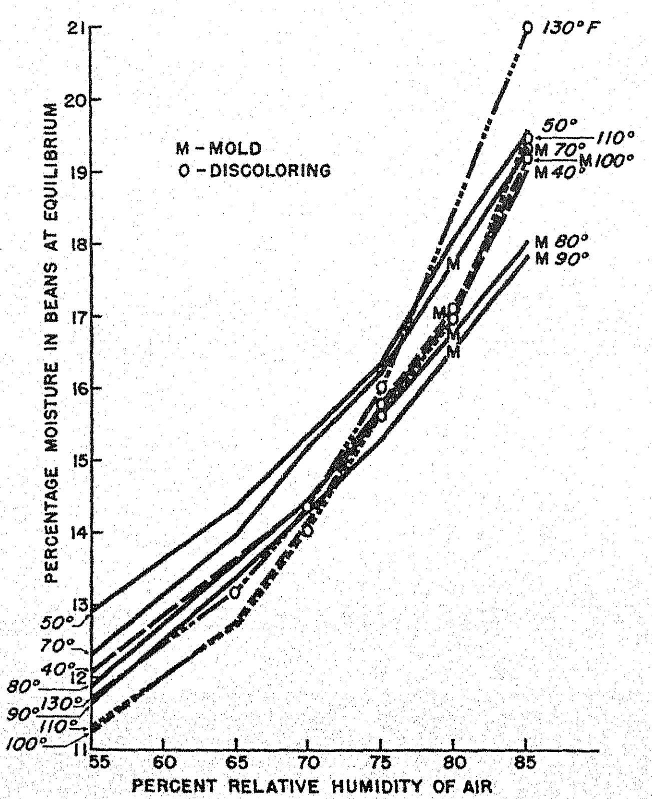

FIG. 3.—The average moisture contents at each relative humidity and temperature (table 1) are shown in the curves to show the change in moisture content as the relative humidity changed at various fixed temperatures.

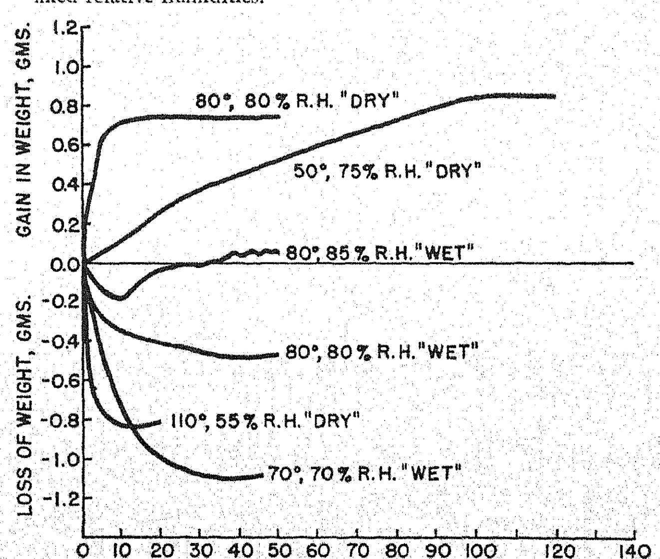

FIG. 5.—The curves show the rate of loss or gain in weight of the bean samples when stored at various relative humidities and temperatures.

beans with a moisture content of 16.4% is put into storage at 50°F. Examination of figure 3 shows that this gives a relative humidity of the atmosphere between the beans of 75% or a vapor pressure of 75% of that of water at 50°F. (75% of 9 mm.). If these beans gradually warm up to 90°F., without losing appreciable water, they will maintain a relative humidity of 78%, which corresponds to a vapor pressure of 78% of 36 mm. Thus, the warmer (90°F.) beans, although at the same moisture content, appear to be more moist than the cool (50°F.) beans. It is quite true that the difference seems comparatively small—75 vs. 78% R.H.—but when it occurs at the critical point for spoilage, only a small difference is needed, particularly in view of the more favorable temperature for mold growth. If a small volume of beans became heated, when surrounded by cool beans, the increased vapor pressure, (78% of 36 mm.) at 90°F. would be approximately 3 times the saturated vapor pressure at 50°F. (9 mm.) and condensation would occur on the cool beans, thus increasing their moisture content, and at the same time warming them, so that conditions for molding would be aggravated.

Generally, the "wet" beans seemed more susceptible to spoilage than the "dry" beans. The "wet" beans had suffered considerable deterioration in the field, during harvest. In selecting the 100 beans for each sample, an effort was made to avoid obviously injured beans. Nevertheless, it is apparent that a larger mold spore count developed in these beans, even at low relative humidities. It has frequently been reported that cracked or otherwise injured grain is more susceptible to damage in storage than is sound grain, even when at the same moisture content (1).

Attention has been called repeatedly to the difference in the moisture contents (4) of various materials at different relative humidities, and the relationship of these values to the allowable moisture content in storage. Milner and Geddes (1, p. 163) state, "it is now quite generally agreed that the so-called critical moisture level for any individual species is the percentage moisture at which the seed is in equilibrium with an atmospheric humidity of about 75%." Thus, the moisture contents at 75% relative humidity of barley, oats, corn, and wheat are about 14.4%, 13.9%, 14.4%, and 14.6% respectively, whereas flaxseed, (10.0%) and other oily seeds are materially lower in equilibrium moisture content at this relative humidity. Beans are notably higher (12), with a value about 16.3% to 16.7% moisture, at 75% relative humidity. Thus, the storage of beans at 17 or 18% moisture is not as completely out-of-line as might appear at first glance. Barton (3) shows a spread of about 7% in the moisture contents of the seeds of 6 species at 20°C. and 76% R.H.

This paper presents certain peculiarities that are not ordinarily encountered where only one temperature is used, or where the range of experimental temperatures was between 50° and 90°F. These are:

1. The changes in moisture holding capacity from 90° to 50°F. are about the same as have been previously reported, and are about what would be expected from the ordinary energy relationships of hydrophilic colloids and heats of hydration (8).

2. The decrease in moisture holding ability as the beans became colder than 50°F. seems somewhat remarkable, but is quite in accord with the findings of Barton (3) with a considerable series of seeds. It would be interesting to have a chemical or a physical explanation of this phenomenon.

3. Similarly, the increased hydrophilic character of beans as the temperature increased above 100°F. was unexpected. It seemed associated with discoloration and the development of rancidity. Even though the beans at 130°F. and 85% R.H. were brown, and rancid, they were moist enough to be readily dented with the finger-nail. Other samples of beans at a similar moisture content darkened correspondingly at 130°F., when in closed containers. It seems highly improbable that the apparent high "moisture" content was due to the loss of volatile materials other than water, because the moist beans molded when inoculated, and stored at room temperature.

SUMMARY

Bean samples with an initial moisture content of about 14% and 20% were stored at temperatures of 40°, 50°, 70°, 80°, 90°, 100°, 110°, and 130°F., and at relative humidities of 55 to 85% until the samples reached constant weight. Moisture determination and mold counts were then made on the samples. Samples held at high temperatures, especially when at high relative humidities showed severe discoloration and chemical deterioration. Molding decreased as storage temperatures went below 70°F. or above 100°F. and was particularly prominent at relative humidities above 75% between these temperatures. Moisture contents were uniformly lower at equilibrium at 40° than at 50°F. at the various relative humidities, and progressively lower through the series from 50°F. to 90°F. At about 100°F. an inversion in the curves occurred, and moisture contents became higher, particularly at 130°F., the highest temperature used. The application of these findings to the problems of bean storage is discussed.

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Chemical Stripping and Suckering of Hops[1]

K. R. Keller and E. R. Laning, Jr.[2]

IN THE production of hops in the United States the average annual labor cost per acre, exclusive of picking, is estimated at approximately $200.00. These charges may be allocated to cultural operations such as hoeing, training, stringing, stripping, and suckering. The latter two operations are usually performed simultaneously. Hoeing machines are now used to a limited extent. Since the major portion of hop production phases are dependent upon hand labor, new methods and technics for reducing costs are of primary economic interest to growers. This study was initiated to obtain information on the use and value of chemical agents as an aid in the stripping and suckering operations.

Hop plants are usually hand stripped and suckered a minimum of 3 times during each growing season. The first operation is performed early in the season when the desired number of vines are trained on the strings which are attached to each hill. The string vines are normally stripped free of leaves from 12 to 18 inches above the surface of the soil. Excess vines or suckers around the base of each hill are removed at this time. The second stripping and suckering operation may vary between yards depending upon the grower but is usually done when the vines on the strings are from 6 to 10 feet in height. The string vines are usually stripped to a height of 3 or 4 feet above the surface of the soil and again the suckers are removed from around the base of each hill. It is during the second and subsequent operations that chemical agents may be used for stripping and suckering. The growing tips of the string vines are well above the spray area at this time.

MATERIALS AND METHODS

Two randomized block designs, one consisting of 10 treatments and the other of 25 were superimposed on the variety Fuggles. The trial with 10 treatments was located in the Orgeon State College hop yard at Corvallis, whereas the other trial was located in a nearby commercial yard. Harvest weights in pounds per plot, percentages of the total soft resin content, alpha acid and beta fraction as well as visual rating data were recorded on the former trial in 1953. Harvest weights and visual ratings were obtained from both trials during the 1954 growing season. The treatments were aplied to 5-hill plots in each of 4 replications for each trial. The entries in the field test involving the 10 treatments consisted of a check plot which was hand stripped and suckered and 9 chemical agents. The other trial which involved the 25 treatments consisted of a check (stripped and suckered by hand) and 8 chemical agents each applied at 3 different rates per acre. The materials used and their rates per acre are presented in a following section. All of the chemicals were dissolved in water and applied by means of a 3-gallon hand sprayer. The pressure within the sprayer tank was held at approximately 40 pounds per square inch. Applications were made on June 24 and July 15 in 1953 and on June 17, July 13, and Aug. 9 in 1954. The vines on the strings were approximately 10 to 12 feet high at the time of the first application. An attempt was made to wet all of the leaves, sidearms, and suckers from a height of 4 feet above the ground level downward. The materials were applied in such a manner that dripping of the solution from the foliage was kept at a minimum. The check plots for each replication were stripped and suckered by hand on the same date that the chemicals were applied. The application dates were governed by the time at which the usual hand stripping and suckering operations would have been performed. Visual ratings which indicated the effectiveness of the materials in the removal of the leaves, sidearms, and suckers were recorded just prior to harvest. The check plots received a rating of 1.0. The rating scale varied between 1.0 and 5.0 inclusive. Treatments which received ratings approximating the check plots were considered effective defoliant agents. Entries which were rated as high as 5.0 indicated little or no defoliation. The plots from both trials were harvested during the last week of August. Since no significant differences were noted among the treatments relative to moisture content the yield data were analyzed on the harvest weight per plot basis. Strobile samples for each treatment in each replication of the 1953 trial were analyzed for their percentages of total soft resin content, alpha acid, and beta fraction.

EXPERIMENTAL RESULTS

The results from a study conducted for 2 years to evaluate the effectiveness of chemicals to reduce the need of hand stripping and suckering hops are presented in table 1.

The results from the analyses of the data for harvest weights in pounds per plot for the 2-year summary, the means of which are presented in table 1, indicated that there were significant differences among treatments. A breakdown of the treatment sum of squares into (a) CIPC vs. others and (b) among others with 1 and 8 degrees of freedom, respectively, indicated that a difference existed only within the first comparison. The effectiveness of the chemical agents in the stripping and suckering action and

Table 1.—Chemical defoliant data for Fuggles grown in the College hop yard, Corvallis, Oreg., 1953 and 1954.

Chemical agent*	Rate/acre (40 gal. H_2O) per application	Cost/acre (Chemical agent per application)	Visual rating	Average yield lbs./plot
1. No treatment	——	——	1.0	44.8
2. C I P C	3.6 pounds	6.96	2.0	12.5
3. D N B P Amine	3.6 pounds	6.72	3.8	44.2
4. Na P C P	8.0 pounds	2.24	2.2	41.6
5. Na M C A	16.0 pounds	†	2.0	39.5
6. Na chlorate	4.0 pounds	0.92	2.8	41.4
7. Mg chlorate	4.0 pounds	0.92	2.8	36.2
8. Cyanamid	30.0 pounds	†	2.0	32.6
9. Endothal	4.0 pounds	‡	1.2	37.5
10. Exp. Herb. No. 3	8 gallons	‡	1.5	43.5

* 2. Iso propyl N-(3 chlorophenol) carbamate
3. Triethanol amine salt of Dinitro ortho secondary butyl phenol
4. Sodium pentachlorophenate
5. Sodium monochloroacetate
6. Sodium Chlorate—defoliant grade
7. Magnesium Chlorate—defoliant grade
8. Calcium cyanamide—soluble grade
9. Disodium 3,6-endoxohexahydrophthallate. (This formulation did not contain a wetting agent or ammonium sulfate.)
10. Experimental Herbicide No. 3 (Hydrin)
† No longer in commercial production.
‡ Cost estimates not available.

[1] Technical Paper No. 885 of the Oregon Agr. Exp. Sta., Corvallis, Ore., and A.R.S., U.S.D.A. Contribution of the Departments of Farm Crops and Horticulture of O.A.E.S. and the Field Crops Research Branch, A.R.S., U.S.D.A. Rec. for publication Dec. 30, 1954.

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the cost of the material should also receive consideration in evaluating each of the entries. Considerable leaf injury was noted on the plants above the sprayed level in the CIPC and cyanamid plots. The evidence of this injury alone would suggest that these materials may be detrimental to plant growth. It is doubtful that treatments receiving a visual rating larger than 1.5 would be acceptable to growers as an effective means of stripping and suckering. On the basis of this statement only two of the materials, Endothal and Exp. Herb. No. 3 appear promising. The acceptance of these chemical agents by hop growers will depend largely upon the cost of the materials. Although extensive data is not available on the cost of hand stripping and suckering, preliminary information obtained on the experimental plots at Corvallis indicates that the expense is approximately $12.00 to $15.00 per acre. The summary of the data presented in table 1 and the results from the analyses of the data for harvest weights indicate that at least two of the chemical agents may be worth consideration as a means of stripping and suckering.

Samples of strobiles were collected from each of the plots in the 1953 trial and were analyzed for their percentages of total soft resin content, alpha acid, and beta fraction. The results from the analyses of the data for these three quality factors indicated that there were significant differences among treatments. A breakdown of the treatment sum of squares into (a) CIPC vs. others and (b) among others, indicated that a significant difference existed within the former comparison only. The average percentages for the total soft resin content, alpha acid, and beta fraction for the CIPC treatment and all others including the check were 14.96, 6.36, 8.60 and 12.81, 5.33, and 7.48, respectively. The analyses of the data for the three quality factors and yield suggest that CIPC effects a significant reduction for these characteristics.

Additional information concerning the value of chemical agents as an aid in stripping and suckering hops was obtained in a commercial planting of Fuggles near Corvallis in 1954. The chemical agents used, their rate, and cost per acre per application as well as their average visual rating scores and yield in pounds per plot are presented in table 2.

The results from the analyses of the data for harvest weights in pounds per plot indicated that there were significant differences among treatments. A breakdown of the sum of squares for treatments into a high yielding and a low yielding group suggested that these groups differed in harvest weights. The low yielding group was composed of treatment numbers 2, 3, 7, 10, 13, 16, and 17. No significant differences in yield were noted among the treatments in the high yielding group. Within the high yielding group leaf injury was noted in the two higher rates for Na P C P, Cyanamid, Na Chlorate, and Mg Chlorate. The high yielding treatment plots which received an average visual rating of 1.5 or lower and which did not exhibit leaf injury were as follows: Na M C A treatment 9, all rates of Endothal, and the two higher rates of the Exp. Herb. No. 3. Although treatment 9, Na M C A, appeared promising in this trial, it may be eliminated from future consideration since it is no longer in commercial production. The results from the analyses of the harvest weights and the data presented in table 2 indicate that either Endothal or Exp. Herb. No. 3 may be of value in the stripping and suckering of hops. It should be mentioned that no yields were recorded for treatment 4 since all of the string vines died shortly following the first application as a result of the action of the chemical agent involved. None of the stock plants was killed since a good regrowth of suckers in those plots was noted later in the season.

Table 2.—Chemical defoliant data for Fuggles grown in a commercial hop yard, Corvallis, Oreg., 1954.

Chemical Agent*	Rate/acre (40 gal. H_2O) per application	Cost/acre (chemical agent per application)	Average visual rating	Average yield lbs./plot
1. Check	——	——	1.0	43.95
2. Na Arsenite	0.8 lb.	0.30	2.0	32.24
3. Na Arsenite	1.6 lb.	0.60	3.0	19.39
4. Na Arsenite	3.2 lb.	1.20	——	0.00
5. Na P C P	4.0 lb.	1.12	3.0	38.60
6. Na P C P	8.0 lb.	2.24	2.7	40.52
7. Na P C P	16.0 lb.	4.48	2.2	32.44
8. Na M C A	4.0 lb.	——	2.2	35.58
9. Na M C A	8.0 lb.	——	1.5	37.26
10. Na M C A	16.0 lb.	——	1.2	28.12
11. Na Chlorate	2.0 lb.	0.46	2.0	34.72
12. Na Chlorate	4.0 lb.	0.92	1.0	37.09
13. Na Chlorate	8.0 lb.	1.84	1.0	22.68
14. Mg Chlorate	2.0 lb.	0.46	2.0	37.86
15. Mg Chlorate	4.0 lb.	0.92	1.2	33.50
16. Mg Chlorate	8.0 lb.	1.84	1.0	28.76
17. Cyanamid	7.5 lb.	——	2.5	32.48
18. Cyanamid	15.0 lb.	——	2.0	38.21
19. Cyanamid	30.0 lb.	——	1.2	36.36
20. Endothal	2.0 lb.	——	1.5	40.91
21. Endothal	4.0 lb.	——	1.0	41.44
22. Endothal	8.0 lb.	——	1.0	38.48
23. Exp. Herb. No. 3	4.0 gal.	——	1.7	40.91
24. Exp. Herb. No. 3	8.0 gal.	——	1.0	41.44
25. Exp. Herb. No. 3	16.0 gal.	——	1.0	39.61

* Refer to table 1 for chemical formulas except for Agents 2, 3 and 4, which are Sodium arsenite.

DISCUSSION

The acceptance and use by growers of chemical agents as a method for stripping and suckering hop plants will depend upon several factors: availability of labor, ease of application, influence on yield, effectiveness, and cost. Recent trends in hop production practices have been toward more mechanization. A lack of adequate numbers of laborers when most needed in the hop yards has practically forced this situation. The application of chemical sprays for stripping and suckering by means of low pressure tractor drawn sprays is quite possible and could be readily adapted by most growers.

The information presented herein suggests that some chemical agents may be used satisfactorily for the stripping and suckering operations. Preliminary estimates for the formulation of Endothal used in these trials indicates that the cost of the material would make it worthy of consideration as a means of reducing expenses in the stripping and suckering operations.

Since there are differences among chemical agents as well as among rates of application within an agent on resultant yield and quality in hop strobiles, growers must therefore take necessary precautionary measures prior to the use of the various materials. The use of chemical agents for stripping and suckering operations would require rather careful preparation of the sprays with regard to rates per acre. The more readily soluble materials would perhaps be more satisfactory for grower use.

It must be remembered that the results from the data presented herein are of a preliminary nature and should not be interpreted as those which might be expected under all conditions. Because of the intense interest by producers, it seemed justified to present the data that had been collected to date on this phase of hop production.

SUMMARY

Experimental trials were conducted on the variety Fuggles in hop yards near Corvallis, Oreg., in 1953 and 1954 to evaluate the use of chemical agents as a method for stripping and suckering hop plants. The results from the analyses of the data for harvest weights and the percentages of the total soft resin content, alpha acid, and beta fraction indicated that there were differences within each analysis among the treatments. Treatments were noted which were equal to the check, stripped and suckered by hand, for each of the factors studied. The effectiveness of some of the chemical treatments, as measured by a visual rating, in the stripping and suckering operation were equal to the check. The results from the analyses of the data presented indicates that several of the chemical agents used in these trials may be of value in the stripping and suckering of hop plants.

A Comparison of Hill and Conventional Yield Tests Using Oats and Spring Barley[1]

W. M. Ross and John D. Miller[2]

TESTING and breeding methods with small grains are fairly well established, with variations depending upon land availability, labor, seed supply, desired statistical precision, and convenience. Though few small grain experimenters have used anything but short rows for line evaluation, corn investigators were introduced to the ear-to-hill breeding method in 1934 by Jones and Singleton (3). Jugenheimer and his group at Illinois[3, 4, 5] (2) have used the hill method extensively and with success for both development of corn inbred lines and evaluation of hybrids. The main advantage claimed for replicated corn hill tests was the larger volume of material that could be observed and tested in relatively small areas.

Swanson (4) planted grain sorghums in hills in 40-inch rows using 6-, 12-, 18-, and 24-inch spacings keeping total plant populations constant by varying number of plants per hill. There was an apparent variety × spacing interaction with highest yields from 6-inch spacings.

Bonnett and Bever (1) in 1947 reported use of headhills as a small grain plant breeding technique, and in 1951 Bonnett[6] experimented with hill yield tests in small grains. Yields and ranks with oats in hills compared favorably with rod-row tests of the same varieties, but differential winterkilling in winter wheat gave a poor relationship in that crop.

[1] Joint contribution from the Field Crops Research Branch, A.R.S., U.S.D.A., and the Fort Hays Branch, Kansas Agr. Exp. Sta.; Contribution No. 87 from the Fort Hays Branch Exp. Sta. Rec. for publication Jan. 19, 1955.

[2] Associate Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A., and Assistant Professor, Kansas Agr. Exp. Sta.

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[4] Jugenheimer, R. W. Efficient development and testing of corn inbred lines and hybrids. Amer. Soc. Agron. Abs. 1949, pp. 6–7.

[5] Schertz, K. F. Comparative accuracy of single hill and larger plots for testing three-way crosses of corn. M.S. Thesis. Univ. of Ill. 1950.

[6] Bonnett, O. T., University of Illinois. Unpublished data.

METHODS

At Hays, Kans., in 1952 and 1953 the oat and spring barley variety tests were planted in hills and rod-rows as well as 1/50 acre drill plots. Drill plots were not grown in 1954, but comparisons were made that year with rod-rows and hills. Additional nurseries also were compared in 1953 and 1954. In these tests each hill, like a rod-row or drill strip, was considered a separate plot.

Hills were planted with a hand corn planter, replicated and randomized, and spaced 1 foot apart in 1-foot rows. The entire test was surrounded by border hills. Seeding rates were either 24 or 25 seeds per hill; this about equals the recommended bushel per acre drill rate of both oats and spring barley for the area. In 1954 three seeding rates were used, but only data from the 24 seed rate were entered in the calculations in tables 1, 2, and 3.

Though entries remained constant within methods of a given test, replication number for each method was determined by the practical considerations involved in any yield test. Randomized block designs were employed in all tests except the 1953 advanced oat and advanced barley rod-rows where a simple and a triple lattice were used, respectively. However, in the combined analyses of table 2, randomized block data were used.

Drill plots were harvested with a combine while rod-rows and hills were threshed with a Vogel machine. The bushel yield per acre for hills is conveniently calculated by multiplying the gram yield per hill by 2 for barley and 3 for oats.

RESULTS AND DISCUSSION

Yield test data in the Great Plains are subject to great variability because of drought, heat, and other natural factors. This largely explains the high L.S.D.'s often required at low yield levels and the high coefficients of variability sometimes shown for individual tests summarized in table 1.

It is evident, however, that variability in hill yield tests was higher than with other methods, primarily because of the great multiplication required to place hill yields on a bushel per acre basis. In spite of precautions, seed losses occurred from lodging, shattering, and harvesting, and difficulties were encountered in threshing small lots of seed without loss.

Differences in yield levels among methods in table 2 were expected and are explained on the basis of location, method

Table 1.—Statistical summary of individual oat and spring barley yield tests used in methods of testing comparisons at Hays, Kans., 1952–54.

Year	Test	Method	No. entries	No. repls.	Av. yield bu./A.	L.S.D. at 5%	C. V. %
1952	Oat variety	plots	12	3	24.3	6.8	16.4
		rod-rows	12	4	21.4	4.5	14.6
		hills	12	8	14.9	7.3	48.7
1952	Barley variety	plots	5	3	23.1	4.4	10.2
		rod-rows	5	4	14.6	4.6	20.8
		hills	5	10	16.2	6.2	41.6
1953	Oat variety	plots	8	4	13.9	2.3	11.4
		rod-rows	8	4	30.9	2.7	5.9
		hills	8	8	20.1	4.9	24.2
1953	Oat advanced	rod-rows	36	3	23.5	5.0	13.2
		hills	36	6	14.7	6.1	36.7
1953	Barley variety	plots	5	4	15.0	2.7	11.7
		rod-rows	5	4	19.9	3.5	11.4
		hills	5	8	20.0	N.S.	24.7
1953	Barley advanced	rod-rows	25	4	22.1	3.0	9.8
		hills	25	6	17.8	5.1	31.5
1954	Oat variety	rod-rows	7	6	65.6	9.7	12.8
		hills	7	10	50.5	9.7	19.4
1954	Barley variety	rod-rows	6	6	50.4	4.9	8.1
		hills	6	10	48.5	N.S.	22.9
1954	Barley advanced	rod-rows	28	3	47.7	13.3	16.8
		hills	28	10	48.6	11.0	25.6

of harvest, machine adjustments, and individuals involved in handling the crop. Similarly varietal differences and differences between replications in a given test were expected and obtained in many cases.

The validity of using one testing method in place of another is based on the fact that varieties perform similarly under both systems. This was not always the case in these tests since in the combined analyses of table 2, a variety × method interaction was found four out of nine times. On the basis of crops, an interaction occurred once in four cases for oats and three in five for barley. Stated conversely, the oat varieties performed alike three out of four times and the barley two out of five times under the different methods.

When varietal yields were correlated between tests as shown in table 3, similar relationships were found. Eleven of 17 correlations were significant; seven of these were with oats and four with barley. Though interest was primarily in the hill comparisons, it is noted that the barley variety tests did not correlate significantly in rod-rows and plots. However, rod-row plots are commonly used by experimenters as substitutes for drill plots in small grains.

In comparisons involving hills, five of six varietal yield correlations were significant for oats and four of seven for barley. Plot and hill yields were significantly correlated in both comparisons with oats but significantly correlated once in two comparisons of barley.

In general, the data point to a better relationship between varietal yields of oats than barley when different testing methods were used. Apparently barley is more prone than oats to react differently in hills than in rows though there is indication of some differential reaction in oats.

Table 2.—Combined analyses of oat and spring barley yield trials, Hays, Kans., 1952–54.

Test	Mean Squares									
	D.F.	Varieties	D.F.	Methods	D.F.	Varieties × methods	D.F.	Blocks within methods	D.F.	Error
1952 Oat variety	11	636.50**	2	1,339.12**	22	37.72	12	166.22**	127	24.45
1952 Barley variety	4	185.39**	2	403.75**	8	8.37	14	46.00	56	28.44
1953 Oat variety	7	339.34**	2	2,409.67**	14	19.84	13	20.59	88	13.68
1953 Barley variety	4	98.49	2	188.58**	8	39.27*	13	34.30*	52	18.27
1953 Oat advanced	35	59.34**	1	5,635.68**	35	27.27	7	76.52**	243	25.27
1953 Barley advanced	24	104.23**	1	1,157.91**	24	26.78	8	90.58**	189	24.92
1954 Oat variety	6	1,032.31**	1	12,690.90**	6	276.56*	14	142.32	84	99.72
1954 Barley variety	5	161.08	1	79.34	5	309.16**	14	376.37**	70	84.60
1954 Barley advanced	27	799.25	1	56.00	27	1,244.83**	11	3,027.31**	292	375.85

* Significant at the 5% level.
** Significant at the 1% level.

Table 3. — Correlations of varietal yields of oats and spring barley under different testing methods, Hays, Kans., 1952–54.

Year	Test	Comparison	r
1952	Oat variety	Rod-rows vs. hills	+0.886**
1952	Oat variety	Rod-rows vs. plots	+0.885**
1952	Oat variety	Plots vs. hills	+0.729**
1952	Barley variety	Rod-rows vs. hills	+0.938*
1952	Barley variety	Rod-rows vs. plots	+0.769
1952	Barley variety	Plots vs. hills	+0.946*
1953	Oat variety	Rod-rows vs. hills	+0.961**
1953	Oat variety	Rod-rows vs. plots	+0.948**
1953	Oat variety	Plots vs. hills	+0.876**
1953	Oat advanced	Rod-rows vs. hills	+0.241
1953	Barley variety	Rod-rows vs. hills	+0.314
1953	Barley variety	Rod-rows vs. plots	+0.761
1953	Barley variety	Plots vs. hills	+0.349
1953	Barley advanced	Rod-rows vs. hills	+0.557**
1954	Oat variety	Rod-rows vs. hills	+0.830*
1954	Barley variety	Rod-rows vs. hills	−0.224
1954	Barley advanced	Rod-rows vs. hills	+0.620**

* Significant at the 5% level.
** Significant at the 1% level.

Table 4.—Summary of rate of seeding oats and barley in hills, Hays, Kans., 1954.

	Oats			Barley		
Rate—seeds/hill	12	24	36	12	24	36
Rate—lbs./acre	30	60	90	40	80	120
Yield—bus./acre	41.0	50.5	53.1	44.6	48.5	54.5
L.S.D. 5% level—bushels	(3.3 among rates)			(4.1 among rates)		
C.V. %—all levels	(26.9)			(26.7)		

To determine if seeding rate had an influence upon varietal yield, three rates—12, 24, and 36 seeds per hill—were used in 1954 with the oat and barley varieties. Data are given in table 4 and show a difference among rates in both crops, but no variety × rate interactions were found. Though the 36-seed rate produced a significantly higher yield in barley and tended to be the highest in oats, it is doubtful if this would hold true in most years, for 1954 was unusually favorable for spring small grains at the Hays station and tolerated high seeding rates.

In addition to yield data, heading, height, and lodging notes were collected from the oats and barley hills in 1952. Because of difficulty in measuring these characters, the data were of little value and no attempt was made in subsequent years to take anything but yield data. Competition among hills seemed to level out varietal differences in these characters. Test weights also were taken but were difficult to measure because of limited seed.

There are certain other factors to consider relative to hill tests. Cost of operations such as packeting seed, marking envelopes, record keeping, and note taking, are constant regardless of plot size. These may account for greater effort and expense than with the same test using conventional methods because more replications appear to be required when using hills.

Advantages of hill testing are: a small area required for experimentation (1 square foot per plot), a small amount of seed needed for planting, and use of randomized blocks instead of more complicated designs because of low soil variability. In 1952 the barley varieties were planted in hills in two 5 by 5 latin squares and the oats in two semi-latin squares. Analyses were made for both latin squares and randomized blocks. Mean squares of the error for barley were 11.80 and 11.36 in latin squares and randomized blocks, respectively, while for oats they were 5.88 and 5.91, respectively, where gram yields were analyzed.

Hill yield tests, from the breeding standpoint, possess some merit for screening large numbers. Tests can be made with early generation material that otherwise would be impossible because of limited seed. Hill tests are not proposed to replace conventional small grain techniques but, carefully used, might be a valuable supplement.

SUMMARY

1. Comparisons of varietal yields of oats and spring barley hill tests with rod-rows and drill plots were made, and yield levels among methods differed significantly seven out of nine times.

2. Variability in hill tests was always higher than in other methods.

3. Better relationships existed between varietal yields of hill tests and other methods with oats than with barley. Of six comparisons involving oat yields in hills, five had significant varietal correlations. Only four of seven correlations were significant when the same comparisons were made with barley.

4. Using combined data involving all methods, variety × method interactions were significant once in four analyses for oats but three in five for barley.

5. Data on heading, height, lodging, or test weight could not be taken with enough precision to measure differences among varieties in hills and were deemed of little value.

6. Hill yield tests with small grains have value only as a supplement to present testing methods when large numbers of lines are to be screened, seed supply is scarce, and land is limited.

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Isolation of Kenaf for Seed Increase[1]

Melvin D. Jones, Carlos Puentes, and Rene Suarez[2]

KENAF *(Hibiscus cannabinus* L.) has complete flowers, similar to those of cotton, with many anthers borne on a staminal column adnate to the pistil. The nature of the pollen is such that wind is not an agent in pollen dispersal; thus, any crossing that might occur results from insect activity. The flowers are large, conspicuous and attractive to insects.

The production of seed is complicated by natural crossing in areas using more than one variety. The handling of several strains on a breeding farm also presents a problem.

This paper contains data on the extent of natural crossing occurring in Kenaf in Cuba and recommendations for the isolation of breeding materials and for seed increase.

REVIEW OF LITERATURE

The reports in the literature show a wide range in the amount of crossing occurring in different countries. These differences probably reflect variations in the insect populations and in the amount of Kenaf growing in the areas with both factors being interrelated.

Tamargo and Jones (4) reviewed the literature on natural crossing in Kenaf. The amount of crossing varied from complete self-pollination in central Asia (3) to 3.92% in the variety vulgaris in Russia (5). The amount of crossing for 9 strains grown at Santiago de las Vegas, was determined by Tamargo and Jones (4). The crossing varied from 1.79% in varieties Cuba 797—5 and Java 1X51 to 23.76% in Cuba 1X88A.

In a later investigation, Jones and Tamargo (2) reported that the honey bee, *Apis mellifica* L., was the most important pollinator of Kenaf flowers. The number of flowers visited by the honey bee during a foraging flight varied from 11 to 41 with an average of 20. Individual Kenaf flowers were visited by as many as 49 bees during a day with an average of 16.7 ± 8.7. The peak of honey bee population in the Kenaf field occurred between 11:30 a.m. and 2:00 p.m.

A wasp, *Campsomeris trifasciata* Fabr., was observed also by Jones and Tamargo in the field in large numbers, however, it visited only the nectar glands on the seed capsules during most of the flowering season.

MATERIALS AND METHODS

In 1952 and 1953, tests were conducted to determine the effect of distance and border rows on outcrossing from a source of foreign pollen. A block consisting of 40 rows, 200 feet long with the rows planted 24 inches apart served as the source of genetically marked pollen. In 1952, this block was planted to Java 1X 51 Kenaf (red plants, divided leaves) and in 1953, to Line XIII (green plants, divided leaves). Small blocks consisting of 18 rows 24 inches apart and 40 feet long were planted to Cuba 797-5 in 1952 and to Cuba 108 in 1953. Both of these varieties have green plants with entire leaves. Crossed seed from these small blocks produced hybrids that were characterized by brown stems and divided leaves from the 1952 planting and by green stems with divided leaves from the 1953 planting. These small blocks were planted in September each year and isolated 0, 1, 2, 5, 15, 25, 40, and 60 rods from the genetically marked pollen block. Due to the possibility of some volunteer plants, different areas were used each year. Directions and arrangement of the blocks are shown in figure 1, which also summarizes the results.

Rows in each block were harvested individually and the bulked seed from each row was planted for classification. Total plants and the number of divided-leaf hybrids were determined and the percentage of crossed seeds calculated directly from these counts.

The area around the blocks of Kenaf was kept free of weeds throughout the season. An apiary containing five hives of honey bees was located approximately one mile from the field.

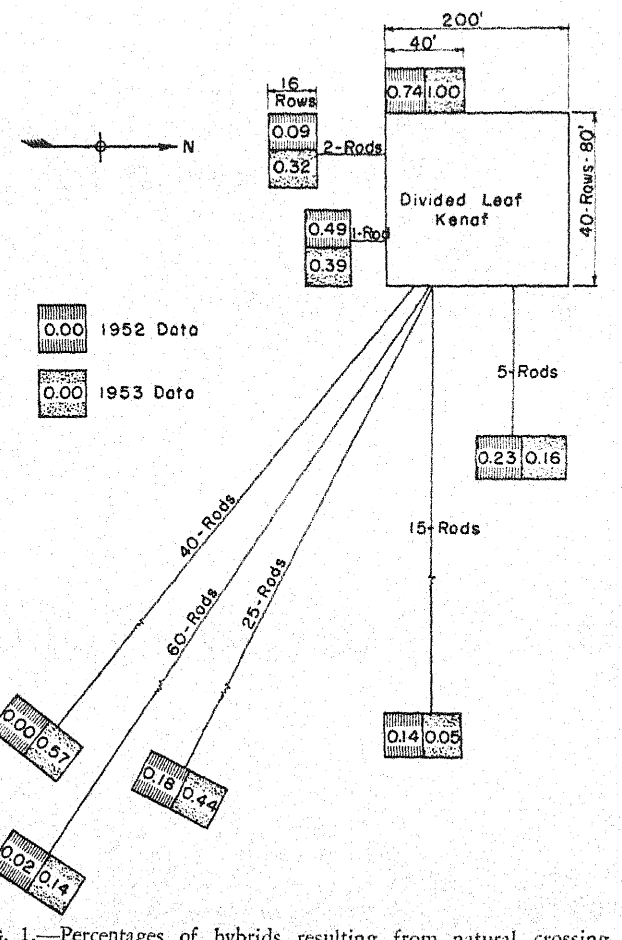

FIG. 1.—Percentages of hybrids resulting from natural crossing and the arrangement of blocks of Kenaf grown in Cuba in 1952 and 1953. The large block contained dominant divided leaf with the small blocks planted to recessive entire leaf Kenaf.

EXPERIMENTAL RESULTS

Table 1 contains data on the total number of plants grown in 1953 and 1954 from the seed harvested from the crossing blocks grown in 1952 and 1953, respectively. The crossing

[1] Contribution from the Comision Cooperativa de Fibras, a cooperative research organization of the Ministry of Agriculture of Cuba and the Foreign Agricultural Service of the U.S.D.A. Rec. for publication Jan. 20, 1955.

[2] Agronomist, Oklahoma Agr. Exp. Sta., formerly Agronomist with F.A.S. stationed in Cuba and Ingenieros Agronomos Comision Cooperative de Fibras, respectively.

from row to row appeared to be random. This randomness was also illustrated by Jones and Tamargo (2) in their studies of charting the foraging flights of honey bees in Kenaf fields. The percentages are low, and border rows failed to produce any reduction in crossing. As a result the data are presented by blocks as a whole rather than on a row basis.

The percentages of crossing varied from 0.74% in the 0 block in 1952 to 0.02% in the blocks isolated 60 rods from the genetically marked pollen (table 1). The results were similar in 1953 with 1.00% crossing occurring in the 0 block and 0.14% at 60 rods. In both years the amount of crossing was variable from block to block. The amount of crossing with increasing distance became less and appeared to be normal for the distances 0, 1, 2, 5, and 15 rods. However, the amount of crossing at 25 and 40 rods was greater than that obtained at two rods.

DISCUSSION AND CONCLUSIONS

Data presented indicate that distances up to 15 rods reduced crossing between nearby fields on a 2-year basis. The amount of crossing that occurred at 25 and 40 rods was high relative to the amount that occurred in adjoining fields.

Since crossing from row to row showed no reduction with increased row number, it suggests that border rows are not effective in reducing crossing.

The varieties, Cuba 797-5 and Java 1X51 that were used in 1952, differed in maturity by 27 days; however, their flowering periods overlapped by approximately 3 weeks. When grown in alternate rows 2 feet apart, Cuba 797-5 showed 3.09% crossing. The strains XIII and Cuba 108 that were used in 1953 varied only 6 days in their maturity. When grown in alternate rows, Cuba 108 showed 11.07% crossing.

The amount of crossing obtained in 1952 and 1953 was quite similar for the various distances. This was surprising since the varietal combinations used were known to produce highly different amounts of crossing when grown in alternate rows.

The necessity for adequate isolation is obvious where strains being increased are genetically distinct; while the results of crossing are less evident, they are just as important where phenotypically similar strains are being grown. For example, all of the old established varieties of Kenaf grown in Cuba are susceptible to the highly destructive anthracnose disease, *colletotrichum Hibisci* (1). New varieties now being released are resistant to Anthracnose, but in order to maintain this resistance, care must be taken to prevent contamination of these varieties through natural crossing with susceptible types. Fortunately, hybrids show considerable vigor and often can be rogued in seed production fields.

The tests reported were not extensive enough to determine the isolation distance required to maintain complete purity of different strains of Kenaf. It is doubtful such distances

Table 1.—Total numbers of plants counted and percentages of hybrids observed in the progeny of green, entire-leaf plants grown at the indicated distances from a field of divided leaf Kenaf in 1952 and 1953.

Distance in rods from genetically marked pollen	1952		1953		2-yr. Ave.
	Total plants	% hybrids	Total plants	% hybrids	% hybrids
0	7964	0.74	2901	1.00	0.87
1	5700	0.49	2280	0.39	0.44
2	5890	0.09	3383	0.32	0.20
5	6090	0.23	3103	0.16	0.18
15	6496	0.14	2164	0.05	0.09
25	6109	0.18	3189	0.44	0.31
40	7733	0.00	2452	0.57	0.26
60	5392	0.02	2184	0.14	0.08

would be feasible in areas of intensive Kenaf culture. These results can be used as a guide in establishing isolation requirements for seed production in areas where crossing percentages are similar to those observed in Cuba.

With small increase blocks of Kenaf on a seed breeding farm, it would be advisable to isolate the blocks as far as possible from other Kenaf. With large commercial seed plantings it appears that five rods would be sufficient. This is being suggested as a minimum requirement, and the possibility of some hybridization is recognized. Increased size of field and rigorous roguing will reduce the overall percentage of contamination in the field.

SUMMARY

Data are presented which show that the amount of crossing between Kenaf fields was low but that some crossing occurred at distances as great as 60 rods. Border rows were ineffective in reducing crossing, probably due to the randomness with which the honey bees visited flowers in the Kenaf fields. It is suggested that small increase blocks on breeding farms be isolated as far as possible from other Kenaf and that large commercial seed plantings be isolated a minimum of five rods.

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Lolium perenne L. X Tetraploid *Festuca elatior* L. Triploid Hybrids and Colchicine Treatments for Inducing Autoallohexaploids[1]

H. L. Carnahan and Helen D. Hill[2]

PERENNIAL ryegrass (*Lolium perenne* L.) and meadow fescue (*Festuca elatior* L.) are used as forage plants, but both are susceptible to crown rust (*Puccinia coronata* Cda.) and to certain *Helminthosporium* spp. Perennial ryegrass under conditions in the Northeastern United States is palatable but deficient in midsummer production while meadow fescue is productive but somewhat unpalatable. Several investigators have crossed species of these two genera in attempts to combine their desirable characteristics and to determine their taxonomic relationships.

L. perenne and *F. elatior* are both normally diploid species (2n = 14). During the course of the present study diploid hybrids were produced from crosses between normal diploid *L. perenne* and colchicine induced tetraploid *F. elatior*. The objectives of this study were (*a*) to ascertain the pairing relationship between chromosomes of the Lolium genome and those of Festuca, (*b*) to obtain information on techniques of inducing chromosome doubling in F_1 clonal material, and (*c*) to produce the autoallohexaploid derivatives of the triploid hybrids.

REVIEW OF LITERATURE

Swayne published a treatise in 1790 suggesting that plants collected as *Festuca loliacea* might have originated as natural hybrids between Festuca and Lolium (6). Peto (8) credits Gartin in 1893 with being the first to have crossed species of Festuca with Lolium. Jenkin (5) described hybrids obtained from reciprocal crosses of *L. perenne* and *F. elatior* and concluded that they agreed in appearance with *F. loliacea*.

Peto (8) studied the cytology of experimental hybrids of *L. perenne* × *F. elatior*, *F. elatior* × F_1 of *L. perenne* × *L. multiflorum* and backcross derivatives of these hybrids. Chromosomes of the 5 F_1 hybrids showed nearly complete bivalent pairing at metaphase I and a chiasma frequency comparable to that of the parents. Four F_1 plants produced no good pollen while one produced 13% of apparently good pollen in anthers which failed to dehisce. He concluded that the poor pollen was due to degeneration between tetrad formation and pollen maturity.

In the backcrosses obtained by using the F_1's as maternal parents, Peto (8) found that 0 to 92% of the pollen was apparently normal. Backcrosses to *L. perenne* produced about three times as much normal pollen as backcrosses to *F. elatior* regardless of which species was the maternal parent in the original cross. While most backcross progenies exhibited complete bivalent pairing at metaphase I, a few of the plants with least fertile pollen exhibited a significant frequency of univalents.

Crowder (1) reported on several interspecific and intergeneric hybrids involving species of Lolium and Festuca and reviewed the pertinent literature. He obtained hybrids involving *F. arundinacea* (2n = 42) and diploid species of Lolium and Festuca. At MI in this material, extreme stickiness made interpretation difficult. Chromosome pairing in the 28 chromosome hybrids ranged from 14 II to 2 III and 22 I. It could not be determined whether the seven chromosomes from *F. arundinacea* that paired with the Lolium complement were the same as those which paired with the *F. elatior* genome. Crowder concluded that certain genomes of *F. arundinacea* have an origin common to the genomes of Lolium diploids and *F. elatior*.

In the backcross progenies of an F_1 [*F. elatior* × (*L. perenne* × *L. multiflorum*)] to *L. perenne*, Peto obtained one triploid plant. Limited cytological observations on this plant indicated that 7, 57, and 36% of the chromosomes at MI were univalents, bivalents, and trivalents, respectively. This plant produced 41% stainable pollen.

Although many investigators have reported on techniques for doubling the chromosome numbers of germinating seeds, there are few reports of techniques for chromosome doubling of clonal material. Hutton (4) obtained the allopolyploids of interspecific Phalaris hybrids by cutting back growth to 2 cm. from the ground and painting plants with an excess of aqueous solution containing 0.2% colchicine and 0.1% spreader. These treatments were repeated for 6 successive days. About 1 panicle in 20 that developed from such plants produced 1 or 2 seeds possessing the doubled chromosome number. The desirability of including untreated material in experiments designed to measure chromosome doubling is emphasized by reports of spontaneous doubling[3] (4). Hutton obtained spontaneous doubling and noted 20% stainable pollen in the undoubled F_1 hybrid *Phalaris tuberosa* × *P. minor*. Carnahan and Hill[3] obtained several 56-chromosome open pollination progenies from an untreated plant of *P. arundinacea* having 35 chromosomes.

Stebbins and Vaarama (9) used a technique, described earlier by Stebbins, to double the chromosome number of several intergeneric *Elymus* × *Sitanion* hybrids. Clonal divisions of F_1's were treated with 0.2% aqueous colchicine for 4 hours and sometimes treatment was repeated on consecutive days. As a rule doubled sectors were identified by their fertility. In some genotypes as many as 80% of the treated tillers produced some seed and in other genotypes no seed was produced even though 30 to 40 treated tillers were grown to maturity. This variable success may indicate a differential clonal response. On the other hand, it is possible that doubling of certain hybrids was not accompanied by fertility.

MATERIALS AND METHODS

Induced tetraploid *F. elatior* clones isolated by Hill and Myers (2) and diploid clones of *L. perenne* grown in the greenhouse were intercrossed following hand emasculations. From several hundred pollinations, a number of shriveled seeds were obtained and planted on White's (10) nutrient agar. Root tips from 12 seedlings revealed 21 chromosomes, evidence of hybridity. Each triploid hybrid resulted from the cross *L. perenne* (2n♀) × *F. elatior* (4x♂). Seven parental combinations provided some diversity of germ plasm among the 12 F_1 hybrids.

Because these sterile triploids were unusually vigorous and leafy, it seemed desirable to attempt to induce fertility by doubling the chromosome number. To accomplish this the lower ends (1½ inches) of 20 well rooted tillers (roots ¼ to ¾ inch long) from each of the 12 hybrids were immersed in beakers with aqueous colchicine solution.

Five tillers of each hybrid were treated with 0.10, 0.25, 0.50 and 1.00% colchicine, respectively, for 12 hours. Temperature was maintained at 72° F. during the treatment and tillers were

[1] Contribution No. 144 of the U. S. Regional Pasture Research Laboratory, Field Crops Research Branch, ARS, USDA, State College, Pennsylvania, in cooperation with the twelve Northeastern States. Rec. for publication January 21, 1955.

[2] Research Agronomist and Assistant Geneticist. The authors are indebted to Anna Storgaard and F. L. Barnett for assistance in the colchicine experiments, to W. M. Myers and A. A. Hanson for contributions during the early phases of the experiment and to R. J. Garber and Paul Grun for valuable suggestions during the preparation of the manuscript.

[3] Carnahan, H. L., and Hill, Helen D. Chromosome distribution in the progenies of pentaploid (2n = 35) reed canarygrass. Agronomy Abstracts, Annual Meeting, American Society of Agronomy. p. 66. 1954.

transferred to fresh water for 12 hours prior to planting. In late summer when plants established from these tillers had made adequate growth, 10 tillers of each were individually potted. Two root tips from each of the resulting 2,400 tillers were sectioned and stained with crystal violet for determination of chromosome number.

Heads of the triploids just emerging from the boot were fixed in 3:1 alcohol-acetic acid, stored at 2° C. and anthers smeared in aceto-carmine. Meiosis was studied on material collected in the field while quartet and pollen studies were made on both greenhouse and field grown material.

EXPERIMENTAL RESULTS

Description of F_1 Hybrids

The 12 F_1 hybrids resemble each other in most respects but vary from medium to dark green in color of leaves. All hybrids flower profusely in the field within a period of 1 week. Difficulty has been experienced, however, in obtaining flowering in the greenhouse. Established plants in the field initiate growth in the spring about the same time as meadow fescue. Growth and leafiness of the hybrids at flowering time exceed both parents but vegetative characteristics resemble meadow fescue more closely. Growth of hybrids during dry midsummer periods has been excellent. Another outstanding feature of the hybrids is maintenance of green color late in the fall after heavy frost and diseases have browned other grasses in the nursery. Some of the hybrids have remained free of crown rust when infection on both parent species has been heavy.

The inflorescence of hybrids is intermediate between the spike of Lolium and the panicle of Festuca (figure 1). Lowest nodes commonly have three to six spikelets. Spikelets occur singly at other nodes and are nearly sessile, progressively approaching the Lolium parent toward the apex. Spikelets, however, are not appressed as in Lolium and are subtended by glumes intermediate in length between those of the parents. Each spikelet has from 9 to 13 florets, a larger number than has either parent. An occasional caryopsis is formed on plants not completely isolated from the parent species. Anthers were present in most florets of 11 of the hybrids. In the other hybrid only one functional anther in about 100,000 florets was observed.

FIG. 1.—Spike of *Lolium perenne* L. (2n), left; lower part and upper part of inflorescence of triploid hybrid center; panicle of *Festuca elatior* (4x), right.

Mr. O. L. Justice[4] has described the "seeds" produced on the hybrids as follows: "In general appearance the seeds resemble *L. perenne* more than *F. elatior* when viewed macroscopically. However, one can observe, even with the naked eye, that the base of the hybrid seed is somewhat narrower than that of Lolium. Individual seeds show variation with respect to the distance that hairs extend down the keels of the palea. Most seeds resemble fescue in this respect, but a close examination reveals some exceptions. If we should test a sample of this seed without knowing anything of its history, we probably would classify some seeds as ryegrass and some as meadow fescue."

Meiotic Behavior of Triploids

Chromosomes in the early meiotic stages showed a pronounced tendency to clump which made intensive analysis practically impossible. The few pre-metaphase cells analyzed suggested that the most common association was 7^{II} and 7^{I}, although some trivalents were also observed (figure 2a). Only one nucleolus was present in each PMC.

[4] From a letter written by O. L. Justice, Head, Testing Section, Seed Branch, Grain Division, AMS, Washington, D. C.

Table 1.—Meiotic behavior of the 12 triploid hybrids.

Parents of F1's ♀ ♂	Metaphase I			Quartets			% of full stainable pollen grains
	No. PMC's	Mean No. I's per cell	$s_{\bar{x}}$	No. examined	Mean No. micronuclei	$s_{\bar{x}}$	
Pr 1 × Mr 2	40	2.78	0.18	155	2.70	0.11	1.2
Pr 1 × Mf 2	40	2.40	.20	190	3.06	.14	2.5
Pr 2 × Mf 4	60	3.87	.19	142	5.32	.16	3.0
Pr 2 × Mf 4	52	3.15	.16	178	3.75	.16	3.2
Pr 3 × Mf 2	25	4.92	.26	152	3.48	.16	0.13
Pr 3 × Mf 2	20	3.60	.34	174	4.42	.15	0.13
Pr 3 × Mf 2	36	4.50	.31	118	3.57	.20	0.14
Pr 3 × Mf 2	68	3.09	.17	111	4.37	.20	0.20
Pr 3 × Mf 2	51	3.90	.21	161	4.29	.17	0.20
Pr 1 × Mf 3	41	4.76	.16	73	4.92	.28	0.07
Pr 1 × Mf 1*	0	—	—	0	—	—	0.00
Pr 3 × Mf 3	35	3.26	.28	190	2.46	.12	0.00
Total	468			1644			

* This plant produced only an occasional anther.

The mean numbers of observed univalents per pollen mother cell at MI for 11 of the triploids are recorded in table 1. Mean number of univalents per cell at MI for the 11 F_1 plants was 3.66. Individual F_1 plants had means ranging from 2.40 to 4.92 with significant differences among means. Of the 468 cells analyzed, only 3 showed no univalents. It is possible that the number of univalents was underestimated for some may have been clumped on the metaphase plate. As the tendency for the chromosomes to be sticky and clumped was apparent in each triploid, selection of interpretable cells may have biased the results. Such bias, however, did not appear to be differential for the various hybrids. The univalents (figure 2b) are presumably mainly from Lolium as the Festuca chromosomes are each represented in duplicate in the hybrids. Lolium chromosomes not observed as univalents were on the metaphase plate and a considerable portion of these were paired with Festuca bivalents to form trivalents (figure 2c). Other associations of three chromosomes may have been due to stickiness.

Most anaphase I figures showed a variable number of lagging chromosomes (figure 2d and 2e). Whole and dividing univalents were observed at this stage with similar frequencies. A few bridges (figure 2f) were observed at AI and these may have resulted from *(a)* crossing over in Festuca chromosomes heterozygous for an inversion or *(b)* crossing over between a Festuca and a Lolium chromosome with homologous but inverted segments.

At telophase I most of the lagging chromosomes had been incorporated into the two nuclei. Although laggards and occasional bridges (figure 2g) were observed at second division, there was very little evidence of any disintegration of cells. Bridges at AII are exceptional. They may have resulted from the same processes mentioned in the case of AI bridges with the added complication of non-disjunction at the first division. Non-disjunction may occur more frequently in material such as the present which is characterized by a significant frequency of trivalents. The AII bridges may also have arisen as a result of a double crossover in an inversion heterozygote involving both chromatids of the normal and one chromatid of the inverted segment.

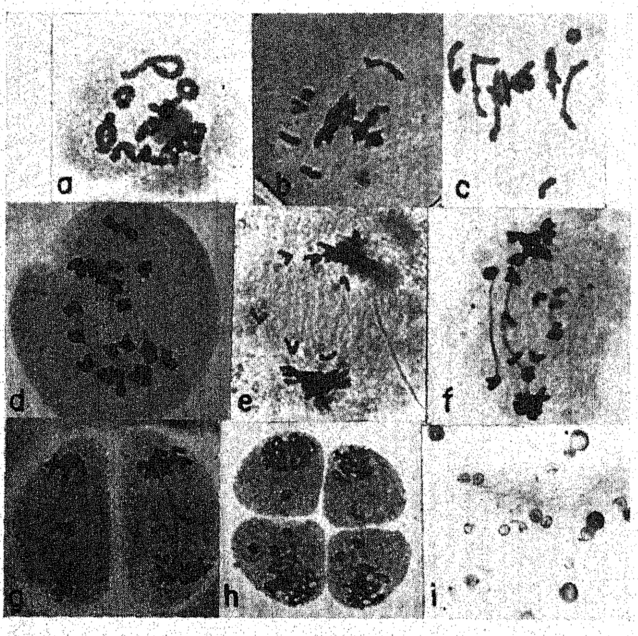

FIG. 2.—Meiotic figures of triploid hybrid of *Lolium perenne* L. (2n) × *Festuca elatior* (4x); *a,* pre-metaphase associations including one "frying pan" trivalent; *b,* early anaphase I, seven univalents off the equatorial plate; *c,* trivalents and univalents; *d,* early anaphase I, 21 chromosomes; *e,* anaphase I, dividing univalents; *f,* anaphase I, two bridges and fragments; *g,* anaphase II, bridge; *h,* quartet with micronuclei; *i,* variable pollen. *a* to *h* circa 1000x; *i* ca. 100x.

Table 2.—Response of 12 F_1's to four concentrations of colchicine applied for 12 hours. (Percent of tillers with 42 chromosomes in one or both root tips).

Clone	Colchicine concentrations				Clone means*
	0.10	0.25	0.50	1.00	
1	28	24	14	6	18.0
2	2	10	2	6	5.0
3	0	2	2	12	4.0
4	8	6	10	4	7.0
5	4	6	4	2	4.0
6	2	8	4	12	6.5
7	2	0	0	0	0.5
8	4	0	4	0	2.0
9	2	6	2	2	3.0
10	4	6	4	6	5.0
11	10	10	10	8	9.5
12	6	6	6	8	6.5
Means for colchicine levels	6.0	7.0	5.17	5.5	

L.S.D. for clone means at 0.05 and 0.01 = 2.2 and 2.8 repectively
* Clones are listed in same order as in table 1 and means are for 200 tillers.

Quartets appeared normal except for the abundance of micronuclei. Mean number of micronuclei per quartet varied from 2.46 to 5.32 for different F_1 plants with a mean of 3.85 for the 11 clones. From 0 to 11 micronuclei per quartet were observed (figure 2h). The occurrence of more than seven micronuclei may be attributed to division of lagging chromosomes and to fragments associated with bridges.

Apparently good pollen was ascertained by counting approximately 1,200 grains per F_1. F_1 plants produced from 0 to 3.2% of well filled pollen grains. It is of some interest to note that 4 F_1 plants resulting from 2 parental combinations produced from 1.2 to 3.2% good pollen while none of the other 8 F_1's from 5 other parental combinations produced more than 0.2% good pollen. The well filled pollen grains were of two sizes as illustrated in figure 2i. Smaller pollen grains may be formed when only the Festuca genome is represented and larger ones when all 7 Lolium chromosomes are present with the 7 from Festuca.

Results from Colchicine Treatments

From each of the 2,400 tillers, two root tips were examined for chromosome doubling with results as indicated in table 2. On the average, the 0.25% colchicine level resulted in the greatest amount of doubling (7.0%). Differences due to colchicine concentrations, however, were not significant. The F value for clones was highly significant when tested against either the general error term or the interaction, clones × colchicine treatments. Spontaneous doubling was not observed in 200 root tips from untreated tillers of the clone showing 18% doubling after colchicine treatment.

The interaction, clones × colchicine concentrations, was not significant, indicating that clones did not respond in a differential manner to the four colchicine concentrations. The amount of doubling in this experiment was unquestionably higher than the observed since two root tips are not an ade-

quate sample for detecting mixoploidy in a given tiller. As leaf width differences appeared to be independent of chromosome number, this character was of no value in identifying tillers with 42 chromosomes.

Of the 2,400 tillers sampled, chromosome number had been doubled in both tips of 61 plants. Six additional root tips were then examined and doubling was observed in all six tips in 23% of the 61 plants. For clones remaining mixoploid, plants showing a high proportion of doubling were divided repeatedly until all tips examined showed 42 chromosomes. Thus, autoallohexaploid derivatives of each of the 12 F_1 clones have been obtained.

DISCUSSION

All of the present triploids resulted from crossing diploid *L. perenne* ♀ with induced tetraploid *F. elatior* as the pollen parent, though reciprocal crosses were attempted. Jenkin (5), Hertzsch (3) and Crowder (1) also reported interspecific or intergeneric crosses among grasses to be more likely to succeed when the maternal parent has the lower chromosome number.

The present triploid hybrids possess a diploid complement of chromosomes from *F. elatior* and a haploid complement from *L. perenne*. Peto (8) has observed nearly complete bivalent pairing in sterile diploid hybrids between these two species. The question arises as to whether autosyndesis might prevail in the amphidiploid hybrid of these species. In the present triploids, where each Festuca chromosome has a homologous partner but the Lolium chromosomes do not, trivalents at MI were fairly common. This most likely indicates some homology between Festuca and Lolium chromosomes, although Myers (7) concluded that some non-homologous pairing occurred in a triploid *L. perenne* plant. The present results should not be interpreted as proof that some allosyndesis will continue to prevail in derived polyploid hybrids in which each Lolium chromosome has a specific homologue.

It will be of interest to study the pairing relationships and fertility of the autoallohexaploids derived from the triploids exhibiting a varying frequency of univalents at metaphase I. If variation in metaphase I univalents has any significance, one might expect autoallohexaploids derived from triploids with the highest frequency of univalents to be the most stable. Differences among triploids in frequency of univalents may reflect to some extent the degree to which Lolium and Festuca chromosomes of specific parental combinations differ. It will be noted (table 1) that both F_1's from the cross Pr 1 × Mf 2 were lower in univalents at MI than any other hybrids. In this respect it is of significance that only 7% of the chromosomes occurred as univalents in a triploid [*F. elatior* × (*L. perenne* × *L. multiflorum*)] × *L. perenne* studied by Peto (8).

Seven chromosomes from Festuca plus a variable number from Lolium in pollen grains would not be expected to affect pollen development so adversely as is indicated in the triploids. Part of this difficulty may be due to unfavorable gene interactions or interactions between Lolium cytoplasm and genes from the paternal complement. Because of trivalent formation, it is possible that many pollen grains did not receive the complete fescue genome. The occurrence of two size classes among filled pollen grains (figure 2i) may indicate that some contain the 7 chromosomes from Festuca while others also include the 7 from Lolium. Union of gametes containing both genomes would result in the production of the amphidiploid.

The significant and marked differences among clones in response to colchicine treatments may be due to such factors as (*a*) variation in number of dividing cells during the treatment, (*b*) variation among genotypes in sensitivity to colchicine effects or (*c*) variation among genotypes in spontaneous rate of doubling. The latter possibility was explored by analyzing 200 root tips from untreated tillers of the F_1 that exhibited the highest rate of doubling when treated with colchicine. No doubled tissue was found. Stebbins and Vaarama (9) have also reported that certain genotypes doubled more readily than others.

The 42-chromosome autoallohexaploids derived by treating the triploids with colchicine are homozygous for all loci in the 7 pairs of Lolium chromosomes. It remains to be determined whether heterozygosity in possible progenies from intercrosses will be accompanied by increased vigor.

The usefulness of this material is unknown. These plants possess several desirable forage characteristics and if fertile and stable may be useful as such. In any case, the fact that several workers have crossed diploid Lolium and diploid Festuca with the hexaploid, *F. arundinacea* suggests the possibility of crossing the present hexaploids with the productive and widely adapted but unpalatable hexaploid tall fescue.

In considering all characteristics of the hybrids, one would conclude that they resemble the two parents more than they do tall meadow fescue, *F. arundinacea*. If it is true as Crowder (1) has suggested that certain genomes of *F. arundinacea* have an origin common to the genomes of *Lolium* diploids and *F. elatior*, then at least one other species would appear to be necessary for the synthesis of *F. arundinacea*.

SUMMARY

1. Twelve sterile but vigorous hybrids with 21 chromosomes were obtained from crossing *Lolium perenne* (2n = 14) with the induced tetraploid *Festuca elatior* (4X = 28). The *L. perenne* diploid served as the maternal parent in each cross.

2. Univalents and trivalents were observed at MI of meiosis with significant differences among F_1's in frequency of univalents. There were occasional bridges at AI and AII and numerous micronuclei in quartets. Very little good pollen was produced (0 – 3.2%).

3. The autoallohexaploids of each F_1 were produced by treating tillers for 12 hours with aqueous colchicine.

4. From an examination of two root tips from each of 2,400 tillers, no significant differences due to rates of colchicine (0.10, 0.25, 0.50 and 1.00%) were noted. Highly significant differences were observed among F_1's in the amount of doubling.

5. It is suggested that the present autoallohexaploids may facilitate incorporation of characters from diploid Lolium and Festuca into hexaploid *F. arundinacea*.

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Effects of Defoliation and Topping Simulating Hail Injury to Soybeans[1]

C. R. Weber[2]

SIMULATED hail damage experiments are conducted primarily to provide information *(1)* to ascertain ultimate damage to a growing crop and *(2)* to understand better the physiological processes of plant recovery. For the most part, past investigations were made with an attempt to imitate actual hail injury. Since hail causes many kinds and degrees of damage, considerable difficulty has been encountered in translating resultant data into information useful in determining the extent of injury. Past investigations involving mutilation to soybeans have indicated that the component factors contributing to the ultimate damage should be considered relative to both their separate and combined effects at various stages of growth. Certain components contributing to simulated hail injury on soybeans have been reported in research bulletins by Camery and Weber [3] and Kalton, *et al.*[4] These components were defoliation percentages, stand reductions, breakages, and shattering and were inflicted at various stages of growth.

This paper is supplemental to these research bulletins. The objective of this study was to examine separately and collectively the effects on seed yield, other agronomic characters, and seed composition of soybeans attributable to defoliation and topping performed at different stages of growth. Literature dealing with this subject has been cited extensively and reviewed in the research bulletins listed above.

[1] Joint contribution from Iowa Agr. Exp. Sta., Ames, Iowa, and the U. S. Regional Soybean Laboratory, Urbana, Ill. Journal paper No. J-2687, Iowa Agr. Exp. Sta., Project No. 1179 and U.S.R.S.L. publication No. 261. This study was supported in part by a grant-in-aid from the Hail Insurance Adjustment and Research Association and 10 mutual insurance companies. Rec. for publication Jan. 28, 1955.

[2] Associate Professor of Farm Crops, Iowa Agr. Exp. Sta., and Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A. The author is indebted to the staff of the U. S. Regional Soybean Laboratory, Urbana, Ill., for the chemical analyses of the seed.

[3] Camery, M. P., and Weber, C. R. Effects of certain components of simulated hail injury on soybeans and corn. Iowa Agr. Exp. Sta. Res. Bul. 400. 1953.

[4] Kalton, R. R., Weber, C. R., and Eldredge, J. C. The effect of injury simulating hail damage to soybeans. Iowa Agr. Exp. Sta. Res. Bul. 359. 1949.

MATERIALS AND METHODS

The Richland variety, because of its use in previous investigations on simulated hail injury, was selected for these experiments conducted on the Agronomy Farm, Ames, Iowa, in 1951 and 1952. Plots were drilled May 19 and 14, respectively, in rows 18 feet long, spaced 40 inches apart, at a rate of approximately 1 bushel per acre. At harvest all plots were trimmed to 16 feet in length. An average stand of 7 to 8 and 10 to 11 plants per linear foot of row was obtained in 1951 and 1952, respectively.

Plants at three different stages of growth were subjected to five topping percentages within three levels of defoliation (see table 1 for description of stages and date of treatment). Thus, 45 treatments were involved, with each replicated four times. A split-split-plot design was employed with levels of defoliation as whole plots, stages of growth as sub-plots and topping percentages as sub-sub-plots.

The 1951 growing season was abnormally cool; this condition delayed growth although precipitation was above normal. The 1952 season was normal or above in temperature and only slightly below normal in precipitation; these factors hastened growth and maturity. Plots were kept weed-free. In both years, the plants ripened before frost and harvesting and threshing was completed under excellent conditions.

Characters studied included seed yield, date of maturity, plant height, lodging, seed weight, and seed quality. Analyses were made for oil and protein percentage and for iodine number of the oil.

Defoliation percentages used were: 0, 50, and 100. For 50% defoliation, one-half the leaf tissue from each node was removed by pinching off one side leaflet and the terminal half of the center leaflet of each trifoliolate leaf. For 100% defoliation all vegetative leaf growth was removed from each node (figure 1 A and B). Cotyledons were not removed. Each node on the main stalk above the unifoliolate leaf node was counted as bearing a trifoliolate leaf.

Topping was done by pulling the terminal bud and the first partially unrolled trifoliolate leaf from the brittle portion at the top of the plant (figure 1 C). Treatments consisted of topping 0, 25, 50, 75, or 100% of the plants within the plot.

EXPERIMENTAL RESULTS

For brevity, stages of growth usually are referred to by the numerical stage or stages which correspond to stages used in previous publications. Calendar dates for stages of growth (table 1) were not used because planting date and seasonal

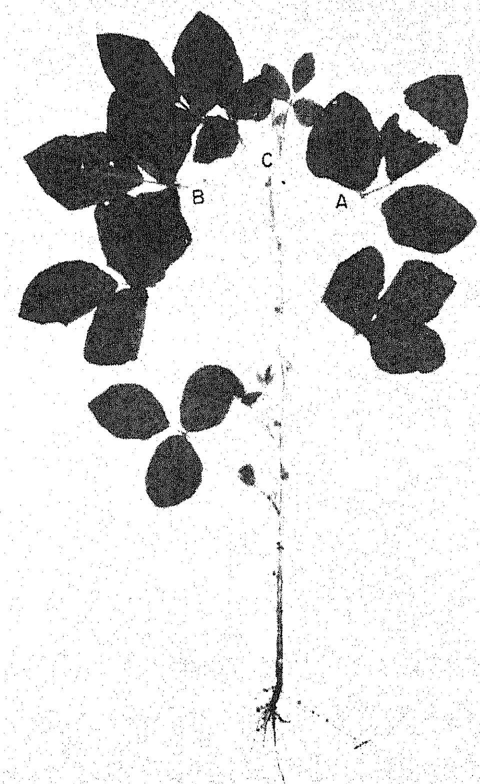

FIG. 1.—Plant at stage 5 illustrating procedures for: A, 50% defoliation; B, 100% defoliation and C, topping.

Table 1.—Stages of growth at which defoliation and topping injury was inflicted on soybeans in 1951 and 1952.

Stages of growth	Date 1951	Date 1952	Average height inches	General description of plant development
1	June 18	June 9	4–5	First trifoliolate leaf completely unrolled. Second trifoliolate leaf just unrolling.
3	July 3	June 23	14–16	Five to six trifoliolate leaves unrolled. Less than 1 percent of plants showing flowers.
5	July 19	July 9	22–24	Nine to ten trifoliolate leaves unrolled. Full-bloom stage with withered flowers in lower leaf axils.

environment influence the time plants reach a particular stage of development.

The following results will be considered in terms of defoliation and topping alone and the two types of injury combined.

Seed Yields

Seed yields in percent of all checks are shown in table 2. The 1952 data, in a more favorable season, supported the trends observed in 1951. In 1952, all injured plants recovered better and, consequently, there was less yield loss generally from defoliation and topping than in 1951. Yield recovery

Table 2.—Mean yields expressed as a percent of all checks resulting from five topping percentages at three stages of growth each with three defoliation percentages, 1951–1952.

	Percent topping	Percent of check — Percent defoliation 0	50	100	Mean
Stage 1	0	97.8	101.1	81.7	93.5
	25	99.7	96.0	79.6	91.8
	50	98.4	95.4	77.4	90.4
	75	89.2	91.9	75.8	85.6
	100	90.3	90.3	72.3	84.3
Mean		95.2	94.9	77.4	89.2
Stage 3	0	99.7	101.1	80.1	93.6
	25	98.6	98.9	74.2	90.6
	50	93.8	89.5	82.8	88.7
	75	91.9	87.4	80.9	86.7
	100	87.9	84.4	75.8	82.7
Mean		94.4	92.2	78.8	88.5
Stage 5	0	102.2	97.0	78.2	92.5
	25	101.6	94.6	76.6	90.9
	50	97.8	91.9	71.5	87.1
	75	97.6	90.6	69.1	85.8
	100	92.5	87.4	70.2	83.4
Mean		98.4	92.2	73.1	87.9
Stages 1, 3, and 5 combined	0	100.0	99.7	80.1	93.3
	25	100.0	96.5	76.9	91.1
	50	96.8	92.2	77.2	88.7
	75	93.0	90.0	75.3	86.1
	100	90.3	87.4	72.6	83.4
Mean		96.0	93.2	76.4	88.5
		Mean of all checks = 37.2 Bu./A.			

from severe injury was greater in the more favorable year as compared to the less favorable year. With 50% defoliation, yield was reduced very little at the three stages. With 100% defoliation yield was reduced approximately 20% at each stage of growth. Removal of the first 50% of foliage had considerably less effect on yield than the removal of the last 50% of foliage (see figure 3 for 0% topping at 0, 50, and 100% defoliation). This has been true for all preceding tests where defoliation was involved. The decreases in yield from defoliation alone were not very different for the three stages.

Yield decreases from topping treatments were not very different for the 2 years. Yield decreases due to topping with no defoliation averaged less than 5% when 25 and 50% topping was performed at all stages and slightly less than 10% with 75 and 100% topping. These decreases in yield were greatest when topping was done at stages 1 and 3 and a lesser amount at stage 5. These results may be explained on the basis that more potential nodes and ultimate leaf tissue were removed by topping at stages 1 and 3 and a lesser amount at stage 5. Figure 2 graphically shows the yield responses from topping in percent of the check. The effects from increased topping injury were additive and approximated a yield decrease of 2.5% for each 25% topping increment.

Yield responses from topping and defoliation were sufficiently similar at each stage to permit their combination by stages of growth. These are shown in table 2 and figure 3. Reductions in yield due to topping were largely additive when combined with 50 and 100% defoliation. The relative yield decreases from the topping treatments were generally similar for 0, 50, and 100% defoliation.

In the analyses of variance for yield mean differences due to defoliations, toppings, and years exceeded the 1% level of probability. Almost all primary, secondary, and tertiary interactions were of little consequence from a statistical as well as from a practical viewpoint. This indicates that the relative yield reductions from topping and defoliation at the three stages of growth were reasonably similar in each year and for combined years.

Effect On Other Agronomic Characters

Two-year means for date of maturity, plant height, and seed weight for topping and defoliation at different stages of growth are given in table 3. Although the 1951 season delayed maturity and the 1952 season hastened maturity (difference of 17 days), the treatments deviated about the same number of days from their respective checks in each of the years. At all stages of growth, complete defoliation delayed maturity considerably more than topping. With 50 and 100% defoliation, maturity was delayed approximately 1 and 8 days, respectively. Maturity was delayed progressively more for 100% defoliation at each of the stages 1, 3, and 5. With 75 and 100% topping, maturity was delayed about 1 day. All other topping treatments had little effect on maturity.

Plant height of the checks was about 3 inches shorter in 1951 as compared to 1952. Height was reduced about 2 inches with 50% and 6 to 7 inches with 100% defoliation. As topping percentages increased, height decreased; this was more noticeable as growth developed through stage 5. Plants at stage 5 recovered less height following injury than those at stages 1 and 3.

Seed weight of checks in 1951 averaged about 0.6 g. per 100 seeds less than in 1952. Seed weights from the various topping and defoliation treatments were not decreased as much in 1952 as they were in 1951. Seed weight was decreased considerably more from 100% defoliation at the 3 stages of growth than from 50% defoliation or any percentage of topping. This decrease approximated 0.8 g./100 or 5%. For each topping treatment, seed weight was not appreciably affected.

The amount of lodging was less in 1951 than in 1952. No definite trends could be established for lodging with any degree of injury at any stages of growth.

Seed quality, as defined by appearance, was not altered by defoliation or topping treatments at any stage of growth used in this study.

Effect On Chemical Characters

The four replications of each treatment in each year were composited into a sample from which protein and oil percentages and iodine number of the oil were determined. The 2-year means for oil content and iodine number of the oil are given in table 4.

Protein percentages are not presented herein as they were not affected appreciably by defoliation or topping treatments at the various stages of growth. The 2-year mean protein percentage for all checks was 40.1.

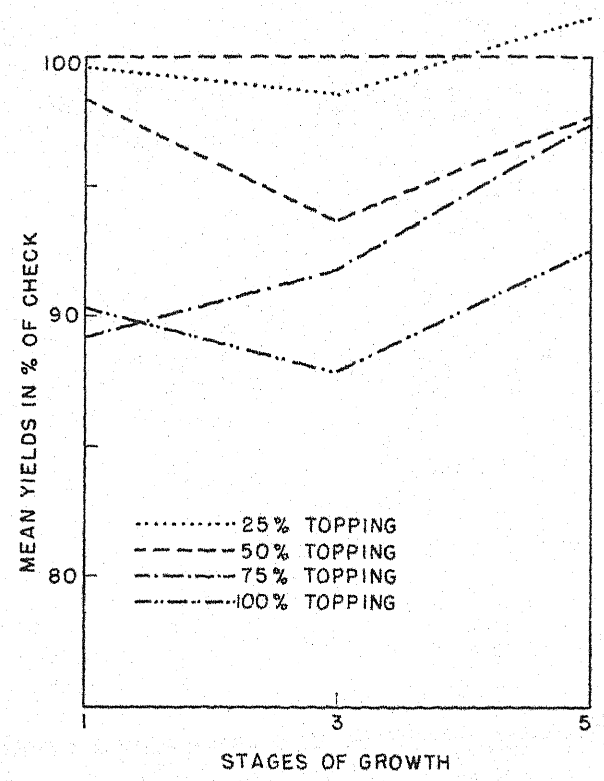

FIG. 2.—Mean yields in percent of check resulting from topping with no defoliation at three stages of growth, 1951–1952. (Mean yield of all checks—37.2 Bu./A.)

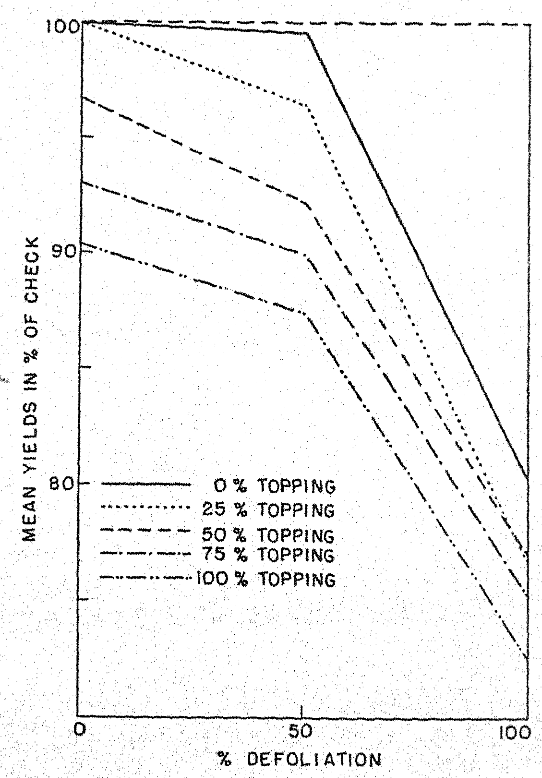

FIG. 3.—Mean yields in percent of check resulting from topping and defoliation combining three stages of growth, 1951–1952. (Mean yield of all checks 37.2 Bu./A.)

Oil percentage was decreased very slightly by the higher percentages of topping at all stages. While 50% defoliation did not appreciably alter oil percentage, 100% defoliation decreased oil content progressively more at each of the three stages of growth, approximating 1% at stage 5.

Iodine number of the oil was increased slightly by topping treatments. With 50% defoliation, iodine number was increased somewhat at stages 3 and 5. With 100% defoliation iodine number increased about 2.0 points with most of the increase occurring at stage 5.

DISCUSSION

Effects of topping and defoliation treatments both singly and combined were studied at relatively early stages of growth. These stages of growth have more recovery potential than later stages. The effects of topping and defoliation gave relatively light yield losses. The most controversial issues in the assessment of injury by hail adjustors usually results from small losses. Where comparisons could be made, the results reported herein agree well with those previously reported.[5, 6] A notable exception was at stage 5 with 100% defoliation alone which yielded 78% of the check in this study and about 64% of check in the cited reports. This may be explained by the more favorable growing season in 1952 as compared to other years. Yield recovery from injury was greater in the more favorable year.

Stem breakage reported by Camery and Weber[7] was defined as follows: "Each plant to be broken was bent completely over at one-half the plant height with a firm pressure applied at the point of bending". Yield reductions from stem breakage treatments were apparent without defoliation but their effects were less apparent with 50% defoliation and almost completely obscured by 100% defoliation. In contrast to stem breakage, yield reductions from topping treatments reported herein were largely additive to reductions from 50 and 100% defoliation.

It is hypothesized that if topping had been applied to later stages of growth than used herein, yield reduction would have become progressively less. All nodes of a soybean plant are usually exposed by stage 7 (beginning of pod formation). Then, any removal of nodes by topping at later stages of growth would be direct as contrasted with the potential node removal in early stages of growth. In addition, terminal nodes usually bear more unfilled pods with smaller seeds than nodes further down on the stalk.

On a given variety the height of pods from the ground level is a function of plant height. Then, injury reducing plant height in early stages of growth may cause greater

[5] Camery and Weber. *Op. cit.*

[6] Kalton *et al., op. cit.*

[7] *Op cit.*

Table 3.—Effect on date of maturity, plant height and seed weight of five topping percentages at three stages of growth each with three defoliation percentages, 1951–1952.

	% Topping	Maturity*			Height (in.)			Seed wt. (g./100)		
		% defoliation			% defoliation			% defoliation		
		0	50	100	0	50	100	0	50	100
Stage 1	0	0	0	+ 5	33	32	27	18.0	18.4	17.8
	25	0	0	+ 6	33	32	26	17.5	18.0	17.0
	50	0	0	+ 6	32	31	25	18.0	17.6	16.9
	75	+1	+1	+ 7	32	32	25	18.0	17.5	17.2
	100	+2	+2	+ 8	32	31	24	18.4	18.2	17.0
Mean		+1	+1	+ 6	32	32	25	18.0	17.9	17.2
Stage 3	0	−1	0	+ 7	32	32	25	17.6	18.0	16.8
	25	0	0	+ 7	32	32	24	17.8	17.7	17.5
	50	0	+1	+ 8	31	30	25	17.4	17.6	17.4
	75	0	+1	+ 8	30	29	24	17.8	18.2	17.7
	100	+2	+3	+ 8	28	28	24	18.1	17.7	17.0
Mean		0	+1	+ 8	30	30	25	17.8	17.8	17.3
Stage 5	0	−1	−1	+ 9	32	30	24	17.8	17.6	16.0
	25	0	0	+ 9	31	28	24	18.5	17.5	16.5
	50	0	0	+10	28	26	22	18.0	17.8	16.8
	75	0	+1	+10	25	24	22	18.0	17.6	16.8
	100	+1	+2	+10	21	21	19	17.0	17.0	17.2
Mean		0	0	+10	27	26	22	17.9	17.5	16.7
Stages 1, 3 amd 5 combined	0	0	0	+ 7	33	31	26	17.8	18.0	16.9
	25	0	0	+ 7	32	31	25	17.9	17.7	17.0
	50	0	0	+ 8	30	29	24	17.8	17.6	17.0
	75	0	+1	+ 8	29	28	23	18.0	17.8	17.2
	100	+2	+2	+ 9	27	27	22	17.8	17.6	17.1
Mean		0	+1	+ 8	30	29	24	17.9	17.8	17.0
Mean of all checks		0			33			17.8		

* Maturity expressed in (—) days earlier and (+) days later than mean for all checks, Sept. 26.

Table 4.—Effect on oil percentage and iodine number of the oil of five topping percentages at three stages of growth each with three defoliation percentages, 1951–1952.

	Percent topping	% Oil			Iodine no. of oil		
		% defoliation			% defoliation		
		0	50	100	0	50	100
Stage 1	0	20.2	19.8	20.1	132.4	131.4	134.0
	25	20.4	20.3	19.8	132.0	132.2	132.9
	50	20.3	20.1	19.8	132.3	131.8	133.6
	75	20.2	20.4	19.8	131.8	132.0	133.2
	100	19.8	20.2	19.8	132.1	132.4	132.6
Mean		20.2	20.2	19.9	132.1	132.0	133.3
Stage 3	0	20.6	20.4	20.0	131.6	131.7	132.6
	25	20.3	20.6	19.8	132.0	132.7	132.8
	50	20.3	20.4	19.9	132.7	132.7	133.2
	75	19.9	20.0	19.9	132.4	132.6	132.4
	100	19.9	20.0	19.8	132.4	132.7	132.8
Mean		20.2	20.3	19.9	132.2	132.5	132.8
Stage 5	0	20.4	20.7	19.6	131.2	132.2	135.6
	25	20.4	20.9	19.8	131.3	132.0	134.8
	50	20.4	20.6	19.6	132.2	132.6	134.9
	75	20.0	20.5	19.4	132.2	133.0	134.4
	100	20.0	20.4	19.4	133.8	134.4	134.6
Mean		20.2	20.6	19.6	132.1	132.8	134.9
Grand Mean		20.2	20.4	19.8	132.2	132.4	133.6
Mean of all checks		20.4			131.7		

combine losses following 100% topping and defoliation than on uninjured plants.

SUMMARY

1. Two widely different types of injury were inflicted on replicated soybean field plots at three stages of plant development in each of two years. Defoliation percentages of 0, 50, and 100 were applied in all possible combinations with topping percentages of 0, 25, 50, 75, and 100 at each of 3 stages of growth up to full bloom. The objective was to make a critical evaluation of defoliation and topping injuries as measured by their separate and combined effects on seed yield and other agronomic and chemical attributes.

2. Yield reductions due to defoliation and topping treatments were relatively small at these stages of growth. The effects from topping alone were additive as well as when combined with defoliation. With 100% topping, yield was reduced less than 10%, whereas 100% defoliation alone gave 20% yield reduction.

3. Maturity date, plant height, and seed weight were affected considerably more by high defoliation percentages than high topping percentages. Degree of lodging and seed quality, as measured by appearance, were not affected by either defoliation or topping injuries.

4. Protein percentage was not altered by the treatments. Oil content was decreased by increased defoliation but it was not appreciably altered by topping treatments. Iodine number of the oil was increased more by defoliation than by topping injuries. Where comparisons could be made the effects of defoliation were in general agreement with previous studies.

The Vapor-Pressure or Relative Humidity Approach to Moisture-Testing for Safe Farm-Storage of Harvested Crops[1]

S. T. Dexter[2]

IN MANY regions of the world, the vast majority of farm products are dried and stored on the farms where they are produced. Millions of tons of hay and billions of bushels of grain are involved.

The determination of the proper degree of drying to permit safe storage has been more of an art than a science, and the techniques learned have been passed on from one generation of farmers to the next. Hay is twisted, smelled, rattled, or scratched with the fingernail, while grain may be bitten or chewed to estimate moisture content and the probability of safe storage. Many efforts have been made over the years to devise simple, more reliable methods to estimate the storability of produce on the farm and hundreds of papers (1) might be cited of studies concerning storability. In general, the moisture percentage in the sample has been related to the spoilage in storage. However, it was soon learned, for example, that flax seed at 13% moisture was much too wet for storage, while white beans at the same moisture were considerably drier than was necessary. Hay might be stored as loose, long hay at 25% moisture, but if allowed to pack without "mowing away" it would heat and mold. Chopped hay might keep without molding everywhere except where it had been tramped upon. Moisture contents required for safe storage ranged widely, depending upon the nature of the material or the storage conditions.

As more scientific studies of the problem continued, it became evident that moisture content, as such, was not the determining factor. Studies of storage in closed containers with air at various relative humidities showed that molding occurred at more or less constant relative humidities of the air surrounding the particles of grain or hay. The air in the bin between beans at 16% moisture may be as damp (75% R.H.) as the air between flaxseeds at 10%, wheat at 14% or alfalfa hay at 16%. Thus, Milner and Geddes (1, p. 163) in reviewing the literature remark: "It is now quite generally agreed that the so-called critical moisture level for any individual species is the percentage at which the seed is in equilibrium with an atmospheric humidity of about 75%".

In view of these facts, a moisture testing system or a farm storage practice based on relative humidity of the interstitial air rather than on percentage moisture seems sensible.

REVIEW OF LITERATURE

In some cases the methods described for farm testing the storability of crops give a percentage moisture value (5, 6, 7, 12, 14) while in other cases, they give an estimate of storability that is related to the relative humidity built up in the air surrounding the sample (4, 7, 11) or some other storage characteristics (8, 17). Isaacs[3] has prepared a bibliography listing about 500 papers dealing with moisture testing, and his list is far from complete. The moisture contents of various farm crops in equilibrium with the air at various relative humidities may be found in numerous publications (1, 2, 9, 15). It is clearly shown that the "equilibrium" works in both directions. If the stored material reaches a moisture content of 14% when stored in air with 75% R.H., so also does air reach a relative humidity of 75% if stored in a closed container with the material when it is at 14% moisture.

Numerous studies (1, Chap. 3; 15) have attacked the problem of storage from another angle, namely the growth requirements, in terms of relative humidity of air, of various specific molds. There is a great difference between molds in this regard; but below a relative humidity of about 75%, there is little or no growth. If a sample is not able to bring the surrounding air up to a relative humidity of 75%, little molding occurs, regardless of the percentage moisture in the sample.

It has been shown that all samples of a given crop—such as winter wheat or spring wheat—are by no means identical in protein or mineral content. In the same way, these samples are not identical in the moisture content at which they will mold, nor will they produce the same relative humidity at any given moisture content (13). The same is true for various hays (9).

It is difficult to establish that the tendency to mold is wholly due to the relative humidity of the air, at any given temperature (3). Certain materials seem remarkably well adapted to mold growth (1, 9). Furthermore, it has frequently been observed that dead or dying seeds are attacked more readily by saprophytes than are fully viable ones (1, Chap. 3, 4). It is so difficult to maintain a reasonably constant relative humidity in all parts of a container, because of the effects of temperature and respiration, that the question is somewhat academic. For most practical purposes, an accurate estimate of relative humidity seems the best single criterion of safe storage available.

In ordinary farm storage, recognition and utilization of this principle is a reliable basis of sound practice. Air with high relative humidity, no matter what the cause, in prolonged contact with farm produce can reliably be expected to produce molding and heating in any hay or grain between the temperatures of about 50° F. and 120° F. Below 50° F., molding will be greatly delayed, while 130° F. (1, Chap. 3) is given as fully lethal for most molds. Many bacteria are active at higher temperatures, but require air with a relative humidity of 95% or more for growth (1, Chap. 3).

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[1] Michigan Agr. Exp. Station, East Lansing, Mich. Journal Article No. 1716. Received for publication Jan. 28, 1955.

[2] Professor of Farm Crops, Michigan State College.

[3] Dr. G. W. Isaacs, Purdue University, unpublished.

EXPERIMENTAL PROCEDURE AND RESULTS

Experiment No. 1

Experiment 1 was intended primarily to determine the rate of drying of long hay in an ordinary mow. First cutting, long, mixed alfalfa-smooth bromegrass hay, with a moisture content between 20% and 25% according to analyses of samples for each load, was rapidly placed in a mow 18 by 40 feet to a depth of about 14 feet in a wood-frame basement barn. There were large cracks between the boards on the barn walls. During the 10-day period of storage, there was no rain. Thermometers were buried in the hay in an attempt to detect differential heating. Other samples were chopped and stored, tightly packed, in steel drums.

When the hay was removed after 10 days of storage, the moisture content was found to be between 12% and 15%. There was no evidence of either heating or molding. The drying rate, between 0.5% and 1.0% per day, obviously required a considerable movement of air through the hay. The chopped hays, tightly packed in steel drums molded perceptibly when the moisture content was as high as 19% or higher. Samples at 25% moisture molded badly when stored in steel drums.

Experiment No. 2

Experiment 2 was run to investigate the rate of establishment of equilibrium between the moisture in the air and in hay in a closed container.

Freshly cut alfalfa was cut into pieces 1 inch long and spread on the laboratory table to dry. At intervals, a sample was taken for testing and placed in a stoppered gallon jar, in which were mounted two thermometers. One thermometer served as the dry-bulb-thermometer, while the other was a wet-bulb, moistened with saturated salt (NaCl) solution (7). The sample was allowed 5 minutes to reach equilibrium, after which it was shaken for 1 minute and the thermometers were read. Table 1 shows the results.

It is plain from the table that the samples of hay did not reach an appproximate equilibrium with the surrounding air in the course of a few minutes, or even within 3 hours,

Table 1.—Thermometer readings and percent dry matter of alfalfa samples dried in the laboratory.

Time	Dry bulb °C.	Wet bulb (Sat. NaCl) °C.	T_d-T_w °C.	Percentage dry matter
2:30 p.m.	27.4	30.1	−2.7	31.8
3:30	26.3	28.8	−2.5	34.2
4:30	26.5	29.1	−2.6	35.0
7:00	26.9	29.2	−2.3	39.6
10:30	26.8	29.0	−2.2	44.5
9:30 a.m.	27.3	29.4	−2.1	50.8
11:30	27.7	29.2	−1.5	58.5
2:30 p.m.	28.6	29.2	−0.6	70.0
2:30	29.6	30.2	−0.6	70.0*
5:00 p.m.	28.7	28.4	0.3	75.3
5:30	28.1	26.7	1.4	75.8
8:30	28.2	28.3	−0.1	75.8†
10:00 p.m.	28.4	26.3	2.1	90.1
Stored in airtight cans for several days to come to equilibrium:				
	27.5	29.0	−1.5	74.4‡
	25.9	26.7	−0.8	77.4‡
	27.4	28.0	−0.6	79.2‡

* This sample was rolled and crushed in the hands and then re-run, shaking for 3 minutes.
† This sample was held in the sealed bottle from 5:30 to 8:30 and then re-run.
‡ Samples were not moldy but had silage-like smell.

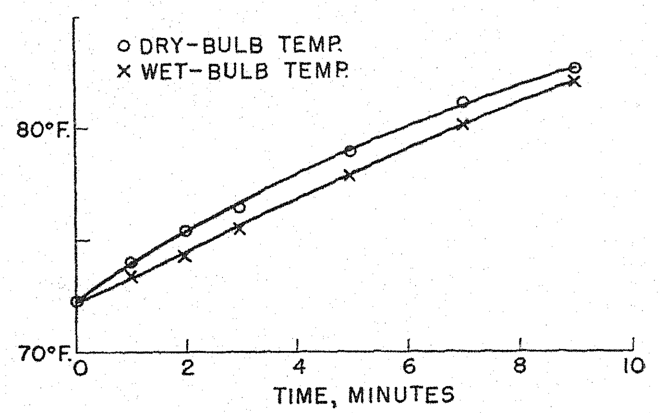

FIG. 1.—A sample of wheat was continuously heated by mechanical stirring in a tight metal container. The two curves show the dry-bulb and the wet-bulb temperature of the atmosphere above the grain. From Isaacs.

since alfalfa hay with 25% moisture content will maintain an equilibrium relative humidity of approximately 85 to 87% rather than about 75% as the table might suggest. The amount of dry surface exposed to the air, with hay, is so much greater than the area of wet surface that this might be expected. Yet, in a matter of 5 minutes, the relative humidity of the surrounding air was built up in the case of samples with about 75% dry matter, to about 75% relative humidity, whereas such samples on long storage would give relative humidities at equilibrium of 85 to 87% (9). In the "salt test" (4) as applied in the field, damp salt can plainly be seen sticking to the damp cut ends of hay that is dry enough to store, although the salt as a whole is not damp.

Experiment No. 3

Experiment 3 was run to investigate the rate of establishment of equilibrium between samples of grain and air in a closed container, and to test the difference between wet-and-dry-bulb readings as a function of temperature. Hundreds of samples were run with various grains, by shaking a sample of about 300 to 400 g. in an insulated quart bottle with a stopper through which two thermometers were inserted (7).

In order to get a slowly rising temperature, an experiment originally run by Isaacs (unpublished) was repeated. A sample of wheat was placed in the metal container of a "Master Moisture Meter",[4] and stirred continuously with a motor driven device for 10 minutes. The rise in temperature reported by Isaacs was about 1° F. per minute. Isaac's curve is shown in figure 1.

From the curve it will be observed that the temperature difference between the bulbs was slightly over 1° F. at the maximum difference—at 2 minutes and 73 to 74°, and that it *decreased* to a difference of about 0.8° F. when the dry bulb temperature reached 83 to 84° F. This is precisely what the theory of equilibrium moisture calls for, since the sample at 83° F. has the vapor pressure of a sample about 0.5 or 0.6% higher in moisture content at the 10° F. lower temperature (10). His results suggest that the grain sample was essentially in equilibrium with the surrounding air at all times, even though the temperature was changing continuously. In earlier trials, the same slight tendency was shown, (7) when samples were run at various room storage temperatures. Table 2 shows the results of the experiment that attempted to duplicate Isaac's results.

Although the tendency toward a decrease in difference with a rise in temperature was very small, the last reading

[4] Once manufactured by the C. H. Baldwin Co., Lansing, Mich.

Table 2.—Wet and dry bulb temperature readings when wheat was stirred violently in a closed container.

Minutes	Dry bulb C.	Wet bulb (Sat. NaCl) C.	Difference ($T_d - T_w$) C.
30 sec.	27.3°	27.5°	−0.2°
1 min.	27.7	28.1	−0.4
1:30	27.8	28.3	−0.5
2 min.	28.3	28.8	−0.5
3 min.	28.8	29.4	−0.4
4 min.	29.4	29.9	−0.5
5 min.	30.0	30.5	−0.5
6 min.	30.4	30.9	−0.5
7 min.	30.8	31.5	−0.3
8 min.	31.3	31.8	−0.5
9 min.	31.5	32.1	−0.4
10 min.	31.4	32.2	−0.8*

* Left 1 minute without stirring and then stirred briefly.

may give a reason. The energy from the vigorous stirring was absorbed by the grain, which was heated almost 0.5° C. per minute. In turn, the grain heated the air. There was inevitably a slight lag in this heating, which got larger as the temperature rose, because of the decided cooling of the uninsulated metal container by the outside air. In the original description of this method of moisture determination it was specified that the container be insulated from the outside air, and from other unavoidable disturbing factors, and a well-insulated milk bottle was used as the container, and shaken by hand, thus avoiding such a notable and objectionable change in dry-bulb temperature. In any case, the two examples indicate the rapidity with which apparent equilibrium is established. After several hours in the tight container, the same reading was obtained on the grain as after 2 minutes of stirring. The differences due to ordinary room temperature variations are small, amounting to not more than 0.5% moisture, and usually less.

When, because of excess surface drying, it is necessary to grind a sample, considerable dust accumulates on the wet bulb (7). Isaacs[5] states that this may be completely avoided by using a double rubber bulb to pass air through the sample and over the thermometers, much as was done by Gaus (11) in testing cotton bales.

DISCUSSION

Several methods have been described which utilize the vapor pressure concept in testing for safe storage of farm crops.

The "salt test" (4) makes use of the fact that saturated solutions of various materials, including common salt, have specific constant relative vapor pressures, and that, in the case of salt, this is very near to 75% R.H. over a large range of temperature. Thus, dry salt takes up water to form a saturated solution when the air is more moist than this, and the salt becomes sticky. Similarly, a saturated salt solution will not evaporate unless the relative humidity of the surrounding air is lower than 75%. Obviously, such a solution on the bulb of a thermometer will indicate, by cooling, when evaporation takes place. This is the principle of the "modified wet-and-dry-bulb thermometer" test (7) for storability. This principle has repeatedly been used in other ways.

[5] *Op. cit.*

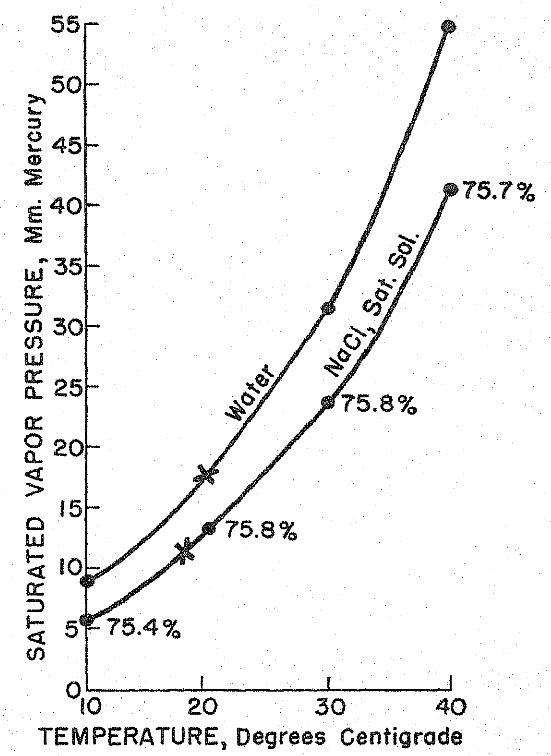

FIG. 2.—The curves show the saturated vapor pressure of water and of a saturated solution of sodium chloride over the temperature range of 10 to 40°C. (Int. Crit. Tables, McGraw) and the ratios of the two at intervals.

In any of these cases, estimation of the relative humidity built up by the product in question gives an accurate insight into the storage behaviour of the farm product, quickly, inexpensively, and without weighing a sample.

Figure 2 shows the vapor pressure curves for water and for a saturated solution of common salt.[6] The figures given at the various temperatures on the NaCl curve are the ratios of the vapor pressures, or the relative vapor pressure (relative humidity) of the air over the salt solution. Supposing the dry-bulb reading to be 20° C. and the wet bulb (NaCl) reading 18° C. as located by the X on each curve. The curves show that these would correspond to vapor pressures or approximately 11.5 mm. and 17.4 mm. or a relative humidity of 11.5/17.4 or 66%, which is somewhat drier than is necessary for safe storage. In general, if the wet bulb (NaCl) is 1° C. colder than the dry bulb, the sample should store without trouble—usually about 71% R.H. Milner and Geddes (1) consider 74% R.H. or less, sufficiently dry for ordinary storage of dry grain.

It is necessary to keep in mind, however, that there are various conditions of storage. In general, storage conditions can be divided into three rough categories. 1. Storage in tight bins or tightly packed bales involves an atmospheric condition in which the moisture in the produce is essentially in equilibrium with the moisture in the interstitial air. 2. Storage in mows or stacks, in which there is a moderate circulation of air, and where equilibrium is never quite reached. 3. Storage in open cribs, where circulation of air is great, and moisture interchange from product to air and the reverse is comparatively unhindered. As was indicated

[6] International Critical Tables. McGraw.

in experiment 3, the development of essentially complete moisture equilibrium can be rapid, and in such a case, a potentially dangerous relative humidity can quickly be reached in the absence of ventilation. In testing such cases for moisture, this must be kept in mind.

Experiments 1 and 2, however, explain the seeming discrepancy in the use of the salt test for hay. Hay came to equilibrium with air in a closed container relatively slowly; in a mow, it lost water comparatively rapidly. Similar hay samples stored in a container that prevented air exchange molded. In the case of hay stored in the mow, the movement of air replaced the humid air on the surface of the stems of hay with drier air and thus prevented the establishment of a relative humidity high enough to support mold growth. In the case of the similar hay stored in drums, air exchange was negligible, and the relative humidity was able to build up to the full equilibrium value, which was high enough to support mold growth.

In testing such samples on the farm for moisture content and safe storage, such facts should not be ignored. For example, it is a common observation among farmers that the moisture inside the stem of hay rarely causes as much trouble in storage as the dampness on the outside. Dampness on the outside of hay that is comparatively low in moisture has been shown in laboratory experiments to be taken up by the hay with astonishing slowness, in comparison with wheat or beans. Such moisture on the surface of hay would exert almost the full vapor pressure of free water, and would produce relative humidities approaching 100%.

SUMMARY

The theory of testing crops for safe storage by means of the relative humidity approach was discussed and examples were given to show under what conditions the full vapor pressure of the sample was actively functional in producing a detrimental relative humidity.

Experimental studies showed that:

1. Long loose hay lost from 0.5 to 1.0% moisture per day in the first 10 days of storage in a mow during hot dry weather, and did not mold, while similar hay stored in tight containers molded severely;

2. Air in a closed container with hay reached a maximum relative humidity only after several hours of storage, whereas

3. Air in a closed container with wheat reached a maximum relative humidity quickly.

The pertinence of these findings to storage and testing problems is pointed out.

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Effect of Wide Spaced Corn Rows on Corn Yields and Forage Establishment[1]

F. W. Schaller and W. E. Larson[2]

THE possibility of establishing forage crops in "wide-row" corn has created considerable interest in Iowa. Some farmers see such a practice as a way to eliminate the relatively low-profit oat crop and still get grass-legume crops seeded for hay or pasture. Others see a possibility of using this practice to establish cover crops and thereby grow corn more frequently in the rotation. The cover crop would help prevent erosion and also provide extra organic matter to plow under.

Studies with corn planted in wide spaced rows have not been conducted in Iowa prior to the work presented in this report. However, some earlier work has a relationship to this technique. For example, forages were seeded as cover crops in normal 40- or 42-inch corn rows in many different locations in the state during a 15-year period.[3] Results showed that successful stands were obtained in less than 3 out of 5 years. In many of the years when stands were good, the amount of growth was very limited and provided little in the way of erosion protection or green manure.

Some row spacing studies with corn (1, 2) have been conducted in Iowa. However, the widest spacings were only 42 inches. The results showed that small yield increases were obtained from rows closer than normal, but that in general 40- or 42-inch rows were about right for efficient corn production.

Reports from other states on "wide-row" corn studies are also very limited. Stringfield and Thatcher (4) have reported work in Ohio. They showed that under good fertility and seasonal conditions corn yields held up well even when corn rows were widened from 40 to 80 inches. They also obtained successful stands of wheat, ryegrass, and alfalfa in corn rows 60 to 80 inches apart.

The studies here reported were conducted to test, under Iowa conditions, the feasibility of establishing forage crops in corn planted in wide rows and to determine the effect of row widths on corn yields.

METHODS

1952 Experiments

Preliminary "wide-row" corn plantings were made in 1952 at Castana on Ida silt loam soil and at Independence on a Carrington soil. Plots were large and were randomized and replicated 4 times. The soil was well fertilized according to soil tests. At both locations the treatments consisted of corn grown in rows spaced alternately 40 and 80 inches and corn grown in normal 40-inch rows. The planting rate for corn was adjusted to give the same planting rate per acre in each row system.

Corn was cultivated 3 times, and forages were seeded in all plots with a narrow grain drill the first 10 days in July. The interplanting included a number of forages, and they are listed with the experimental results (table 2). Corn yields were obtained from each plot, and observations on the forage seedings were made several times during the summer and fall.

1953 Experiments

Studies were expanded in 1953, and were conducted at a number of locations. The test plots varied in size but were at least 20 feet wide and 80 feet long. A randomized block design with four replications was used. The corn row widths used in each experiment and the forage interplantings are given with the experimental results (tables 1 and 2).

All plots in 1953 were located on silt loam soils and fertilized sufficiently to produce high corn yields. Row fertilizer and nitrogen side-dressing were used on all plots at equal rates per acre. In addition to row fertilizer, 400 pounds per acre of 10–10–10 was plowed down on the low fertility soil at Independence.

The corn was planted with a corn planter equipped with small furrow openers at Independence and Beaconsfield, with a lister planter at Castana and Shenandoah, and with a conventional corn planter at Marcus. In all cases the planter was set to plant about 16,000 seeds per acre in both 40-inch rows and alternate 40- and 80-inch rows. In the 80-inch rows, 12,000 seeds per acre was the planting rate.

At all locations the corn was rotary hoed once and cultivated twice. The forage seedings were made just after the last cultivation which was about June 25. The seed was machine-broadcast and then lightly covered in the 8-inch spaces by rolling, harrowing, or by towing a ½-inch log chain behind the seeder. No covering was accomplished in the 40-inch rows.

At most locations a mower was used to clip weeds in the wide spaced rows in August or early September.

1954 Experiments

Three experiments were conducted during 1954 to compare corn yields and forage interplantings in variable spaced corn rows. Corn row spacing, date of forage seeding, and forage mixture are given with experimental results (tables 1 and 2).

At Beaconsfield and Independence the corn was planted with a planter equipped with small furrow openers. A conventional planter was used at Seymour. The planters were set to plant about 16,000 kernels in 40-inch rows and 12,000 in the 80-inch rows. In all cases heavy rates of complete fertilizer were applied to insure high corn yields and successful forage establishment. The corn was rotary hoed and cultivated 3 times at all locations.

The forage seed was applied through the "grass seed" attachment of a grain drill. After seeding, the soil was rolled in the wide spaced rows and was packed with the tractor wheels in the 40-inch rows. Forage observations were made and corn yields were obtained as in the other years.

An additional experiment was conducted at Independence in 1954 to compare dates of seeding forages in 80-inch row spaced corn. The corn for this test was drilled, using small furrow openers, at a rate of about 12,000 kernels per acre. The corn was adequately fertilized to give high yields, and an additional 100 pounds per acre of 0–20–20 was drilled in 7-inch bands about 1 inch deep over the entire soil surface at corn planting time. It was thought that this would give adequate fertilization for the forage seeding. A meadow mixture was then seeded at 3 dates, namely, *(1)* at corn planting time, *(2)* after the first cultivation, and *(3)* after the third cultivation. The exact treatments are given with the experimental results (table 5).

A mixture of red clover-alfalfa-timothy was seeded on all plots. In addition, winter rye was also planted on the plots seeded at corn planting time in the hope it would help control weeds. This plot was mowed 3 times during the season, and the plots planted at the 2 later planting dates were mowed twice. Corn and forage observations and corn yields were obtained as in other years.

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[1] The Iowa Agr. Exp. Sta., Ames, Iowa, and the Soil and Water Conservation Branch, A.R.S., U.S.D.A., cooperating. Journal Paper No. J-2690, Project No. 787, of the Iowa Agr. Exp. Sta. Received for publication Feb. 4, 1955.

[2] Extension Agronomist, Iowa State College, and Soil Scientist, Eastern Section of Soil and Water Management.

[3] Unpublished results of the Iowa Agr. Exp. Sta.

Table 1.—Effect of row spacing on yield of corn in Iowa.

Experiment location	Yield (bu. per acre) Row width (in.)			Stand (plants per acre) Row width (in.)		
	40	80	40-80-40	40	80	40-80-40
			1952			
Independence	73.3	——	67.4	11,209	——	9,562
Castana	123.0	——	110.3	15,094	——	15,398
Mean	98.2	——	88.8	13,156	——	12,480
			1953			
Independence I	103.5	71.3	——	13,980	8,685	——
Independence II	90.7	70.3	82.8	15,736	9,066	12,524
Marcus	122.5	97.2	95.0	16,077	12,312	10,817
Beaconsfield	76.1	66.6	——	15,069	10,199	——
Shenandoah	88.7	67.1	——	11,896	8,154	——
Castana	82.7	65.7	83.2	12,325	11,618	11,971
Mean	94.0	73.0	——	14,180	10,006	——
L.S.D. (0.01) for comparing means		12.6				
			1954			
Independence	114.6	80.2	——	12,480	8,678	——
Seymour*	9.7	37.3	——	12,496	10,835	——
Beaconsfield†	31.5	40.2	34.0†	15,621	11,454	13,384†

* An extreme drought in July and early August limited corn yields at these locations. See Table 2 for the moisture deficits.
† Corn planted in 60-inch spaced rows.

EXPERIMENTAL RESULTS

Row Widths and Corn Yields

Corn yields and plant populations as influenced by row widths during 1952, 1953, and 1954 are given in table 1. At Castana in 1952 under excellent growing conditions, corn yields averaged 123 bushels per acre in normal 40-inch rows and 110 bushels per acre in alternate 40- and 80-inch rows. At Independence in 1952 rainfall was deficient, and yields were lower than at Castana. The yields averaged 73 and 67 bushels per acre, respectively, for the 40-inch and alternate 40- and 80-inch spaced rows. The decrease in corn yield caused by widening the rows was 10.5% at Castana and 9% at Independence.

In 1953, corn yields were generally good at all 6 locations, averaging 94 bushels per acre in 40-inch rows and 73 bushels per acre in 80-inch rows. The yields varied considerably between different locations, but this would be expected because of wide variation in soils as well as differences in weather.

When comparing the 1953 corn yields in normal and 80-inch row plantings, it is shown that widening the rows decreased yields an average of 22%. The decreases ranged from 12 to 31% for the different locations. However, in 4 of the 6 locations, the range varied from only 20 to 25%.

Corn was also grown in alternate 40- and 80-inch rows at Independence, Marcus, and Castana. This spacing, when compared to 40-inch rows, resulted in a yield decrease of 9% at Independence and 22% at Marcus. There was no yield decrease at Castana.

Corn stands varied considerably in 1953 at the different locations even though actual planting rates were about the same. In some of the tests, yields might have been higher with increased stands. However, at most locations stands were adequate for good corn yields in the different row spacings.

Three experiments were conducted in 1954. At Independence yields were 114 and 80 bushels per acre, respectively, for the 40-inch and the 80-inch spaced rows. At the other two locations corn yields were actually greater in the 80-inch than in the 40-inch spaced rows. A severe drought limited growth at these two locations, and presumably the greater yields were due to lower plant populations in the 80-inch rows.

Row Widths and Forage Results

The effect of corn row widths on forage establishment is shown in table 2 for all experiments conducted in 1952, 1953, and 1954. The information reported in this table includes seeding mixtures, seeding dates, notes on emergence and stand, and rainfall data for all test locations.

At Castana in 1952, rainfall was favorable and good stands and growth of most of the interplanted crops were obtained. Best stands and growth were made by alfalfa, sweetclover, and the mixture of rye and hairy vetch. Wheat seedings were largely killed by rust by mid-August.

Interplantings at Independence in 1952 were fair to good even though rainfall was much less favorable than at Castana. Amount of growth, however, was limited. Alfalfa, sweetclover, red clover, and hairy vetch were all successful. Rye and wheat were seriously infected with rust and were about gone by mid-August.

At both Castana and Independence, interplantings made much better growth in 80-inch spaces than in normal 40-inch row plantings. Where 40-inch rows were flanked by 80-inch rows (alternate 40-80-inch plantings), growth was no better in the 40-inch spaces than in the normal spaced corn.

The 1952 plantings were not held over to 1953, and consequently no forage yields were obtained.

Table 2.—Effect of corn row widths on the emergence and stand of forage seedings.

Experiment location	Seeding mixture	Meadow seeding date	Emergence (all corn row widths)	Stand of seeding on Nov. 1, Row width (in.) 40	80	40–80	Rainfall as departure from normal for July-Sept.
				1952			
Independence	Wheat; foxtail; rye–vetch; sweetclover; alfalfa–bromegrass–timothy	July 9, 10	fair	fair	——	fair	−5.3
Castana	Wheat; foxtail; rye–vetch; sweetclover; alfalfa–bromegrass–timothy	July 3	good	good	——	good	+1.6
				1953			
Independence I	Alfalfa–red clover–timothy	June 26	good	fair	excellent	——	−1.9
Independence II	Alfalfa–red clover–timothy	June 26	good	fair*	good*	fair*	−1.9
Marcus	Alfalfa–red clover	July 8	good	poor	fair	——	+0.2
Beaconsfield	Alfalfa–red clover–timothy	July 8	good	none	none	——	−7.6
Shenandoah	Alfalfa–bromegrass	June 23	good	poor	fair†	——	−5.2
Castana	Alfalfa–bromegrass	July 2	good	none	none	——	−5.2
				1954			
Independence	Alfalfa–red clover–timothy	June 24	good	fair	good	——	−2.1
Beaconsfield	Alfalfa–red clover–timothy	June 22 &	none	none	none	——	−3.8
		Sept. 17	good	none	none	——	
Seymour	Alfalfa–red clover–timothy	June 23 &	none	none	none	——	−4.8
		Aug. 18	good	none	none	——	

* On April 28 stands averaged 7.3, 11.5 and 9.6 plants per square foot, respectively, for 40-inch, 80-inch and alternate 40-80-inch rows.
† On Oct. 1 stands averaged 6.7 plants per square foot.

In 1953 seedling emergence was good at every location, and satisfactory stands were present in the wide row plantings by mid-July. Then dry weather began to take its toll. By Oct. 1 the stands at Castana and Beaconsfield were complete failures. The stands were fair at Marcus but too spotty to leave for hay or pasture. Stands were fair to good at Shenandoah and excellent at Independence.

Soil moisture appeared to be the main factor in the success or failure of the forage stands seeded in wide row corn. The excellent growth and stand at Independence in 1953 was largely the result of over 6 inches of rain in July plus 2 inches of rain in early August. At most of the other locations rainfall was considerably less in July and August. The fall months were the driest for many years at all locations.

In April 1954 stand counts were made of the forage interplantings established at Independence the previous year. The stands in plants per square foot for all row widths are shown in table 3. It should be noted that separate stand counts were made for the area between corn rows and for an area directly over the corn rows. This was done since it was evident that forage plants were very sparse directly over each corn row. From a large number of measurements it was found that this area averaged about 14 inches wide and was about the same width in both the 40- and 80-inch row spaces.

The data in table 3 show that the total number of alfalfa, red clover, and timothy plants between corn rows was about twice as great in the 80-inch spaces as in the 40-inch spaces. It is also evident that the stands in the 40-inch spaces were not improved by alternating with 80-inch spaces. The total number of alfalfa, red clover, and timothy plants per square foot averaged 8.7 in 40-inch rows uniformly spaced and 8.4 in 40-inch rows planted alternately 40 and 80 inches. For the 80-inch rows the stands averaged 15.2 and 16.5, respectively, for the uniform and alternate planting systems. In the 14-inch strip directly over the rows of corn the stands averaged 4.6 plants per square foot.

Table 3.—Effect of corn row width on meadow stands seeded in corn at Independence, Iowa, in 1953.

Row width inches	Meadow stands on April 28 plants per square foot: Alfalfa	Red clover	Timothy	Total
	Between corn rows			
40	5.4	0.8	2.5	8.7
80	10.2	2.4	2.6	15.2
Alternate 40–80				
40	5.4	0.6	2.4	8.4
80	9.6	2.6	4.3	16.5
	Over corn rows (14 in. wide)			
All widths	3.3	0.3	1.0	4.6

Hay yields and an estimate of weeds in the hay were obtained from the interplantings made in 1953 at Independence. The results are shown in table 4. As might be expected from the stand counts previously presented, hay yields were highest in the 80-inch spaces and lowest in the 40-inch spaces. Hay yields averaged 0.92, 1.75, and 1.37 tons per acre, respectively, for 40- 80- and alternate 40-80-inch rows.

In general, the hay yields were all lower than would normally be expected from the stands present and the kind of season which prevailed. The low yields are believed to be due primarily to low soil fertility. Soil tests made on samples collected after the second cutting showed that both phosphorus and potassium were low to very low. Even

though liberal amounts of complete fertilizer were applied to the corn crop, the carry-over apparently was not sufficient for good hay yields.

From the data in table 4 it is evident that the amount of weeds in the hay was quite high, especially in the 40-inch plantings. Field observations showed that in the 40-inch plantings weeds were well scattered throughout the relatively sparse stand, whereas in the 80-inch rows weeds were confined almost entirely to the area previously occupied by the corn plants.

Table 4.—Yields of alfalfa-red clover-timothy hay obtained in 1954 from stands established in corn at Independence, Iowa, in 1953.

Corn row width (in.)	Hay yield* tons per acre	Weeds† in hay %
40	0.92	55
80	1.75	18
40–80	1.37	40
L.S.D. (0.05)	0.48	
L.S.D. (0.01)	0.68	

* Estimated.
† Total yield from two cuttings.

Corn Yields and Forage Stands As Affected by Forage Seeding, Date, and Number of Corn Cultivations

The effect of 3 dates of forage seeding on corn yields and forage stands is shown in table 5. It is evident from these data that corn yields were markedly influenced by the date of forage seeding or by the number of corn cultivations. For example, 27.7, 59.5, and 79.4 bushels per acre were produced, depending on whether the forage was seeded on May 12, June 10, or June 24, respectively.

The reduced yield of corn caused by the earliest dates of seeding was undoubtedly due to a number of factors. Of these, lack of sufficient moisture and nitrogen appeared to have contributed the most. The treatment seeded at corn planting time was not cultivated. Weeds and the rye grew profusely during May and early June and caused corn growth to be limited from the start. This occurred even though weeds and rye between the rows were mowed when they reached a height of about 6 inches. Nitrogen deficiency symptoms were very evident on the corn despite the early application of 115 pounds of N per acre.

The 20-bushel per acre reduction in corn yield on the treatment seeded after the first cultivation on June 10, as compared to the June 24 seeding, was probably largely due to lack of moisture during an extremely dry July and early August. While weed growth did not appear too severe, it probably reduced the available moisture considerably. Nitrogen did not seem to be limiting on this treatment.

Satisfactory forage stands were obtained with all treatments. The best stand was secured on the treatments where the forage was planted at corn planting time. Also, considerably better stands over the corn row were obtained by earlier seeded treatments.

The amount of forage growth by fall was markedly greater on the treatments seeded at corn planting time than from the other treatments. Growth was also somewhat better on the plots seeded June 10 than on those seeded June 24.

DISCUSSION

It is quite apparent from the data presented that very profitable yields of corn can be grown in rows spaced as wide as 80 inches. On soils of good fertility it appears that at least 75 to 80% as much corn can be expected from 80-inch rows as from normal 40-inch row plantings.

To obtain good yields in wide spaced rows, it is evident that adequate plant populations must be maintained. The studies presented in this report indicate that plant populations per acre in 80-inch rows should not drop more than 25% below that considered best for 40-inch rows. In general, experiments in Iowa (3) indicate that about 16,000 plants per acre are desirable in 40-inch rows at medium to high fertility levels. Studies are not sufficient to determine optimum plant populations in 80-inch rows. However, data in this paper suggest that populations should be at least 12,000 plants per acre for 80-inch rows at medium to high fertility levels.

Three years of study under a wide range of soil and weather conditions have shown that forage seedings in corn are much more successful in wide spaced corn rows than in normal spaced rows. Uniform wide row spacing was considerably more successful than the system of alternate normal and wide spaced rows.

Table 5.—Effect of forage seeding date and number of corn cultivations on forage stands and corn yields grown in 80-inch rows at Independence, Iowa, in 1954.

Date of forage seeding	No. of corn cultivations	Yield* corn bu./A.	Seeding mixture	Stand of seeding Oct. 20, 1954 plants per sq. ft.	
				Between row	Over row†
May 12	0	27.7	Rye–alfalfa–red clover–timothy	13.1	5.4
June 10	1	59.5	Alfalfa–red clover–timothy	8.9	3.5
June 24	3	79.4	Alfalfa–red clover–timothy	9.4	0.8
L.S.D. (0.05)		16.7			
L.S.D. (0.01)		27.8			

* Corn population averaged 8,434 plants per acre.
† Includes an area about 12 inches wide over corn rows.

FIG. 1.—Corn in 80-inch rows and stand of interplanted forage obtained from seeding made on June 26, 1953. Picture was taken Aug. 5, 1953 at Independence, Iowa.

FIG. 2.—Stands of alfalfa-red clover-timothy in early June 1954 which were established in corn from seedings made during June of the preceding year. On the left are stands from 80-inch corn rows and on the right from 40-inch rows.

Too few trials are yet available to predict exactly how often forage seedings in corn will be successful. However, it is evident that chances of favorable results are not as good as in oats since seedings in corn must be made later, and there is more competition from the nurse crop. Rainfall, particularly during July and August, appears to be the most critical factor determining success or failure.

The best time to make seedings in corn is not definitely known, but chances of success appear best when seedings are made as early as possible in June. A good practice would be to plant the corn as early as the season will allow, then make two cultivations and get the forages seeded by June 20. When seedings are made by this time, there is usually moisture in the soil and further rains can be expected. This will allow the plants to get established and sufficiently rooted to withstand less favorable weather during mid-summer. There is also a possibility of making fall seedings for establishing hay or pasture. However, preliminary studies with fall seedings have not been successful during the past 3 years because of unusually dry fall weather.

Observations made in this study have indicated that best forage stands were obtained when seedings were made on smooth, firm seedbeds. In most of the tests forage seeds were broadcast after the last corn cultivation. A corn cultivator leaves the ground loose and quite rough. When a harrow or corrugated roller was used in the wide rows to smooth and firm the seedbed before seeding and to cover the seeds after broadcasting, stands were better and especially more uniform.

Weed control was generally a greater problem in wide rows than in normal spaced rows. The control of weeds in the corn rows was improved by using furrow openers when planting the corn. With the corn plants in the bottom of shallow furrows, it was possible during cultivation to cover weeds at the base of the corn plants without leaving ridges. The normal practice of ridging corn for weed control should be avoided when hay crops are being established since rough ground will interfere with haying machinery. Many weeds frequently developed in wide rows after the corn was "laid by." One or two clippings were necessary to retard such weed growth.

Studies in Iowa have not been conducted to determine the best row width to use for obtaining optimum corn yields and forage stands. It is obvious, however, that as row widths are widened, chances of forage success are increased, but corn yields tend to decrease. Further study is necessary to determine the proper width to give as much corn as possible, yet allow satisfactory establishment of forage interplantings. Present studies have indicated that 80-inch rows are about the minimum width which will allow passage and working room for a small farm tractor between the rows. This has been especially important in the seeding operation and to permit clipping of weeds. It also makes it possible to prepare a seedbed and make fall seedings in fully grown corn.

SUMMARY

Twelve experiments were conducted over a 3-year period to test the feasibility of establishing forage crops in corn planted in rows wider than normal and to determine the effect of row width on corn yields.

Data show that good yields of corn were produced in rows spaced as wide as 80 inches. In these studies 75 to 80% as much corn was grown in 80-inch rows as in 40-inch spaced rows.

To obtain good corn yields in wide rows, adequate plant populations per acre were necessary. It was indicated that plant populations per acre in 80-inch rows should not drop more than 25% below that considered best for 40-inch rows.

Establishment of forages in wide spaced corn rows during late June or early July met with fair success in 1952, 1953, and 1954. Rainfall was usually the most important factor determining the success or failure of forage seedings at the different locations.

It was evident that widening the corn row spacing greatly improved both the stand and growth of the interplanted crop. Uniform wide row spacing resulted in better stands and more growth than the system of alternate normal and wide spaced rows.

A study of forage seeding dates showed that best results were obtained by seeding in early June when soil moisture and rainfall are more favorable. However, it was indicated that early forage seeding may result in reduced corn yields since the number of corn cultivations is reduced and weed competition may be serious. Fall seeding of forages in corn may have possibilities, but results so far have not been successful.

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The Genetics of Yield Differences Associated With Awn Barbing in the Barley Hybrid (Lion × Atlas[10]) × Atlas[1]

E. H. Everson and C. W. Schaller[2]

IN A PREVIOUS paper, Suneson *et al.* (12) described an association of semi-smooth awns and high yield in a backcross progeny involving the transfer of a small segment of chromosome V from Lion to Atlas barley. Such associations which combine quantitative characters (yield) with qualitative characters (awn barbing) are very valuable to the plant breeder. They provide a positive means for selection of desirable quantitative characters which are difficult to follow in a breeding program. However, an understanding of the genetic basis of such associations is fundamental for their greatest utilization. The occurrence of this association in a population derived by back-crossing provided ideal material for a genetic study of yield. After nine backcrosses and subsequent selfing, lines were available which were essentially homogeneous with the recurrent parent Atlas for all chromosomes except for portions of chromosome V between and adjacent to the genes conditioning awn barbing *(Rr)* and rachilla hair length *(Ss)*. Agronomically the derived lines and Atlas were practically indistinguishable.

This discussion is concerned with a genetic study of yield factors located on a segment of chromosome V using the *Rr* and *Ss* genes as markers.

LITERATURE REVIEW

Numerous investigators, listed by Robertson *et al.* (9) have reported F_2 data which satisfactorily fit a monofactorial ratio of 3 rough-to 1 smooth-awn. The symbol *(Rr)* has been assigned to this gene. Two dominant genes, *R* for rough awns (complete barbing) and R_1 for semi-smooth awns (partial barbing), resulting in an F_2 ratio of 12 rough, 3 semi-smooth, and 1 smooth were reported by Griffee (4) and Johnston and Aamodt (6). *R* was epistatic to R_1. It is with the *Rr* gene that this study deals.

A number of investigators (9) have found long-haired rachilla to be dominant to short-haired rachilla and differentiated by a single gene pair. The symbol *(Ss)* has been assigned to this gene.

The major gene for awn barbing *(Rr)* and the gene for rachilla hair length *(Ss)* have been placed in the fifth linkage group with crossover values ranging from 26.5 to 42.7% by Daane (3), Hor (5), and Wexelsen (13). Daane, Hor, and Robertson, *et al.* established coinciding crossover values of 34% in the repulsion phase. Suneson *et al.* (12) reported a crossover value of 30%. This gives evidence that substantially the same *Rr-Ss* segment is involved in the present work.

Investigating the components of yield in cereals (tiller number or heads per unit area, kernel number, and kernel weight), Barbacki (1) reported two cumulative genes for tillering and two or three cumulative genes for kernel weight. Lejune (7) found kernel weight in barley governed by two or three genes, while Boyce (2) found kernel weight in wheat conditioned by one, two, and three genes in three different crosses. An association in wheat between purple straw, controlled by a single gene, and high kernel weight, a quantitative character, was reported recently by Middleton and Herbert (8).

MATERIALS AND METHODS

The materials used in this study originated in a backcross program described by Suneson *et al.* (12). The genetics of the yield differences associated with the awn barbing allele in chromosome V was studied in the hybrid (Lion × Atlas[10]) × Atlas.

Calif. 1306, the composite of semi-smooth awned and long-haired rachilla derivatives *(rrSS)* of the Lion × Atlas[10] backcross, was crossed with Atlas (C.I. 4118), which possessed rough-awns and short-haired rachillas *(RRss)*. A number of homozygous F_2 plants of the genotypes $\frac{RS}{RS}$, $\frac{Rs}{Rs}$, $\frac{rS}{rS}$, and $\frac{rs}{rs}$ were isolated and increased for yield testing (table 1). The recombination types would result from the union of two crossover gametes. If crossing over occurred at random within the *RrSs* segment, the point of crossing over in each gamete would not necessarily be the same. A number of $\frac{RS}{RS}$ and $\frac{rs}{rs}$ F_3 plant families (table 1) were isolated from F_2 plants of the genotype $\frac{rs}{RS}$ (coupling phase heterozygotes). The $\frac{RS}{RS}$ or $\frac{rs}{rs}$ lines from a single F_3 plant family would be formed by gametes with identical points of crossing over, but the point of crossing over would differ between F_3 plant families.

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[1] Contribution from the Agronomy Division, University of California, Davis, Calif., and the Field Crops Research Branch, A.R.S., U.S.D.A. Part of a thesis submitted in partial satisfaction of the requirements for the Ph.D. degree by the senior author. Received for publication Feb. 10, 1955.

[2] Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A. and Asst. Professor, Univ. of Calif., respectively. Grateful acknowledgment is made to C. A. Suneson who provided the material.

Theoretical assumptions regarding homozygosity of backcrossed populations and their similarity to their prototype varieties were discussed by Schaller (10). Suneson (11) presented an extensive evaluation of nine backcross-derived wheats which emphasized the high degree of similarity between recurrent parent varieties and their progenies produced from five or more backcrosses. On the basis of the theory and data presented in the above-mentioned papers, it can be assumed that any measurable differences between the backcross derived lines in yield or other plant characteristics can be attributed to that segment (or segments) of chromosome V which remained intact during the transfer of the *(r)* and *(S)* alleles from Lion to Atlas.

In this study the yield test was used as a genetic tool to study the inheritance of the yield factor or factors associated with the awned barbing and rachilla hair length characters. In 1951–52 the lines with the same homozygous genotypes for awned barbing and rachilla hair length and the same generation of origin were yield tested together. The variety Atlas was included as a check in all tests. In 1952–53, lines which differed significantly in yield from the mean yields of the derived populations in the 1951–52 tests were tested for yield with several lines which had had yields near the mean of the population. Again Atlas was included in each replication as a check. All the yield tests in this study utilized a completely randomized block design. The tests in 1951–52 consisted of 2 planting dates (Dec. 15, 1951, and Feb. 10, 1952) with 15 replications each, whereas the test in 1953 consisted of a single November planting date consisting of 10 replications. Since all the lines were essentially homozygous in respect to plant type and growth, single row plots were used. Yield measurements were based on 16 feet of each plot and the results were analyzed using the analysis of variance.

RESULTS AND DISCUSSION

Since high yield was shown (12) to be associated with the allele *(r)* for awn barbing, most of the $\frac{rs}{rs}$ lines should be more productive than the $\frac{RS}{RS}$ lines. Reversals would indicate crossing over had occurred between the gene for awned barbing and a gene or genes for yield. This evidence would eliminate pleiotropic action and indicate that the gene or genes responsible for the increased yield were located within the $\frac{Rs}{rS}$ segment. No yield differences among the individual $\frac{rs}{rs}$ lines or among the individual $\frac{RS}{RS}$ lines would suggest pleiotropy, tight linkage, or that the gene or genes for increased yield were located outside of the *rS* segment.

Analyzing the yields of the 8 $\frac{rs}{rs}$ F_2 plant families, the between line mean square was significant at the 1% level, thus suggesting a high probability of true yield differences between lines. This would result from crossing over within the segment.

A scatter diagram of the mean yields of the 8 $\frac{rs}{rs}$ F_2 lines and the Atlas check for this test is presented in figure 1. The mean yields of two lines were significantly lower at the 1% level than the mean of the population, whereas the mean yields of three lines were significantly higher at the 5% level, one of which was significant at the 1% level. This significant difference in yield between lines indicated that all lines did not possess the same factors for yield. The low yielding lines fell within the population limits of Atlas and probably lacked the allele or alleles for high yield. These lines would result from crossing over between the *Rr* locus and the locus or loci conditioning yield and would carry the same yield factors as Atlas. These results

Table 1.—Genotypes isolated from the *rrSS* (Calif. 1306—high yielding) × *RRss* (Atlas—lower yielding) cross for yield testing.

Source	Generation genotype formed	Awn Barbing	Rachilla hair length	Number of lines	
$\frac{Rs}{rS}$ F_1	F_2	*RR*	*ss*	12	Non-crossover
$\frac{Rs}{rS}$ F_1	F_2	*rr*	*SS*	12	Non-crossover
$\frac{Rs}{rS}$ F_1	F_2	*RR*	*SS*	5	Crossover
$\frac{Rs}{rS}$ F_1	F_2	*rr*	*ss*	8	Crossover
$\frac{rs}{RS}$ F_2	F_3	*RR*	*SS*	14	Crossover
$\frac{rs}{RS}$ F_2	F_3	*rr*	*ss*	17	Crossover

provided evidence that the association was broken, suggesting this association was due to linked factors and not pleiotropy.

When the yield data of the 17 $\frac{rs}{rs}$ F_3 plant families (from $\frac{rs}{RS}$ F_2 plants) were analyzed, the between line mean square was found to be highly significant. As in the previous test, it is highly probable that there was a real differ-

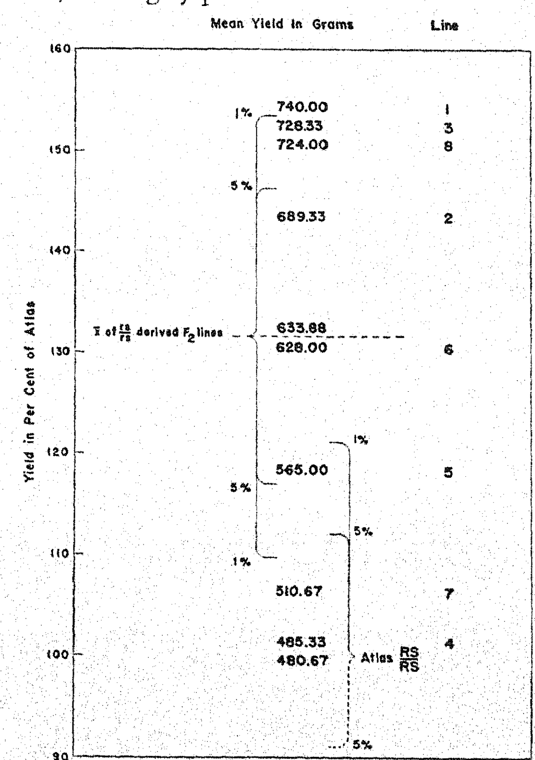

FIG. 1.—Mean yields of 8 $\frac{rs}{rs}$ F_2 plant families in the F_5 generation. Planting date, Dec. 15, 1951.

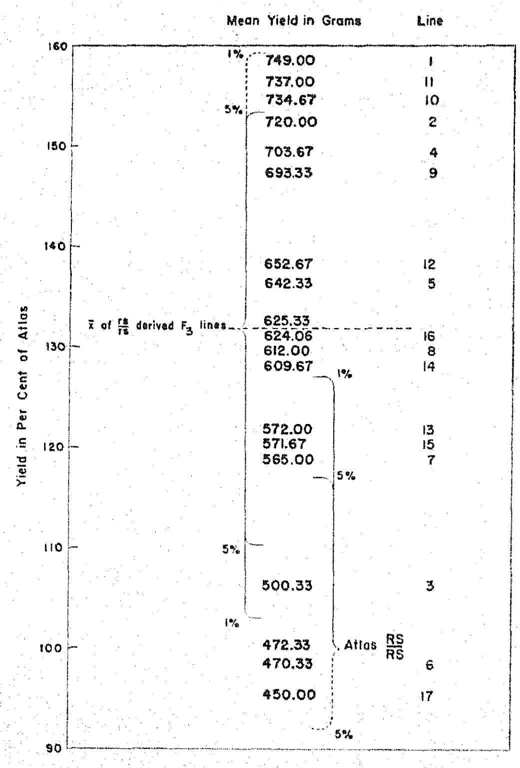

FIG. 2.—Mean yields of 17 $\frac{rs}{rs}$ F_3 families (from $\frac{rs}{RS}$ plants) in the F_5 generation. Planting date, Dec. 15, 1951.

ence in yield between lines, which could result only from recombination within the segment.

A scatter diagram of the mean yields of the 17 $\frac{rs}{rs}$ lines and the Atlas check is presented in figure 2. The mean yield of the $\frac{rs}{rs}$ population was higher than the mean yield of Atlas, which would be expected, since high yield is associated with the *rr* locus. At the upper levels of yield, the means of three lines differed from the general mean of the population at the 5% level of significance. At the lower yield levels, the means of three lines differed from the general mean of the population at the 5% level of significance, two of which differed from the general mean at the 1% level. The three low yielding lines fell within the population limits of Atlas and probably lacked the allele or alleles for high yield. These lines would result from crossing over between the *Rr* locus and the locus or loci conditioning yield and would have the same yield factors as Atlas. These results support the previous evidence that crossing over had occurred.

Six of these lines were retested in 1953. The varieties Atlas and Calif. 1362 (C.I. 9534) included as checks. Calif. 1362 is a composite of smooth-awned, short-haired rachilla derivatives from the cross Lion × Atlas[10] in which the yield-awn barbing association was first noted (12). It was included as the standard for measuring the yield response of this association. The results are presented in table 2. The yield of Atlas and lines 6 and 17 were approximately equal and were significantly lower than Calif. 1362. This confirmed the previous results which indicated that

Table 2.—Yields of selected lines in 1953.

Line No.	Genotype	Ave. Yield (grams/16-in. row)
Atlas	*RRss*	600*
Calif. 1362	*rrss* (comp.)	685†
Fig. 2–1	*rrss*	634
Fig. 2–6	*rrss*	607*
Fig. 2–11	*rrss*	678†
Fig. 2–13	*rrss*	646
Fig. 2–15	*rrss*	651
Fig. 2–17	*rrss*	575*
Fig. 3–5	*RRSS*	635
Fig. 3–8	*RRSS*	661†
Fig. 3–9	*RRSS*	620

* Significantly different from Calif. 1362 at 5% level.
† Significantly different from Atlas at 5% level.

crossing-over had occurred between the *r* allele and the factor or factors for high yield.

The analysis of the 5 $\frac{RS}{RS}$ F_3 families showed that the between line mean square was not significant. None of these lines had mean yields which differed significantly from the mean yield of the population or the mean yield of Atlas.

In the analysis of variance of the yield of the 14 $\frac{RS}{RS}$ F_3 plant families (from $\frac{rs}{RS}$ F_2 plants) the between line mean square was significant at the 1% level. The mean yields of three of the $\frac{RS}{RS}$ lines had exceeded the population mean at the 5% level of significance, one at the 1% level (see figure 3). The mean yield of the $\frac{RS}{RS}$ population approxi-

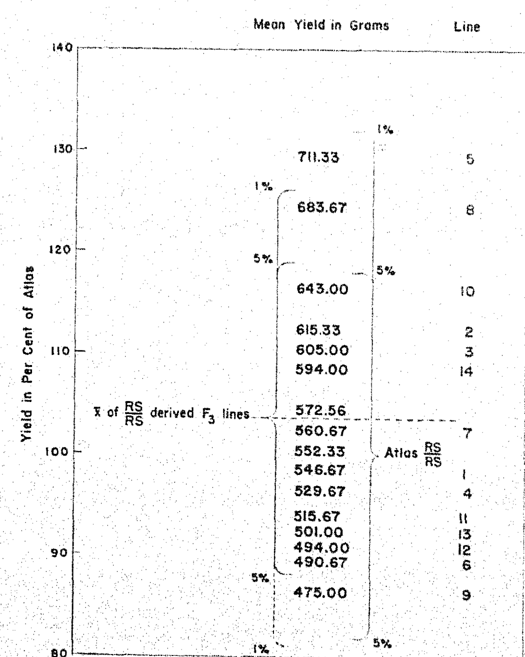

FIG. 3.—Mean yields of 14 $\frac{RS}{RS}$ F_3 plant families (from $\frac{rs}{RS}$ F_2 plants) in the F_5 generation. Planting date, Dec. 15, 1951.

mated the mean yield of Atlas since low yield was associated with the *R* allele. The low yielding line could be either a segregate of low yield genes from the (Lion × Atlas[10]) × Atlas cross or a chance deviation. The two high yielding lines may represent recombinations in which the rough awned character was associated with high yield.

The three lines were retested in 1953 (table 2). The mean yield of line 8 was comparable with that of Calif. 1362 and significantly higher than Atlas. Thus it can be assumed that a recombination between rough awns and high yield had occurred. The low line in 1952 was slightly higher than Atlas, indicating the difference in 1952 was due to a chance deviation. Line 5 was intermediate between the two checks and further testing is needed to determine whether or not it represents a recombination between the loci under discussion.

The recombinations which were identified in this and the preceding tests demonstrated that linkage rather than pleiotropy accounted for the association of the awn-barbing and yield. Furthermore, these tests have indicated that the linked factor or factors governing the yield increase are probably located between the *Rr* and *Ss* loci.

Assuming no crossing over between the *Rr* and *Ss* loci as shown by the retention of the parental genotypes (disregarding double crossing over, which would be extremely rare) it is possible that crossovers might occur just outside the segment. Differences in yield between lines of the parental genotypes would suggest a difference in the genetic constitution of the chromosome regions continguous to the $\frac{Rs}{rS}$ segment in chromosome V. No differences in yield between individual $\frac{Rs}{Rs}$ or $\frac{rS}{rS}$ lines would indicate that the gene or genes for increased yield were located between the *Rr* and *Ss* loci.

An analysis of variance of the yield data of the 12 $\frac{Rs}{Rs}$ lines showed that the lines in this test did not differ significantly in yielding ability. All lines fell within the population limits of the general mean. The mean of the 12 $\frac{Rs}{Rs}$ F_2 lines was 551.0 g. compared with the mean yield of Atlas which was 550.33 g.

When the yield data of the 12 $\frac{rS}{rS}$ F_2 lines were analyzed, there was no evidence that the lines were from different populations. All of the 12 lines fell within the population limits of the general mean.

These results supported data of the previous tests and further established that the factor or factors for increased yield were linked with the *Rr* locus and located between the *Rr* and *Ss* loci.

In the present analysis no positive decision could be made as to whether the increased yield was controlled by a single gene of large effect or a block of linked determinants each of smaller effect, which produced the larger difference when acting together. This determination requires further study.

A most interesting aspect of this study was that of the genetic-environmental interaction. Plantings in December accounted for yield increases of 14 to 32% over that of Atlas. This increase may be due at least partially to a higher degree of cold tolerance possessed by the semi-smooth awned strains as suggested by Suneson *et al.* (12). When the yield tests were planted in February, the gene or genes for increased yield expressed themselves weakly or not at all. It is possible that the factor or factors affect characters such as tillering, kernel number, or kernel weight which find maximum expression under a long growing season with optimum environmental conditions. When late planted, the plant has a shorter growth period with more rapid early development so that it cannot produce the extra tillers, kernels, or kernel weight. Further studies on this phase of the problem are in progress.

The value of the study in practical plant breeding requires no lengthy discussion. Since the yield factor is linked with a readily identifiable character, it can be easily followed in a breeding program. The retention of this association of semi-smooth awns and high yield after 9 backcrosses where the recurrent parent (Atlas) was rough awned, indicates the importance of linkage. It points out the caution that must henceforth be exercised by breeders who select for predetermined types when their effect on productivity and quality are not known. It demonstrates that backcross derived varieties (especially those of species with low chromosome numbers) should probably be tested before they are released, for in other cases the linkage may be unfavorable. The widespread use of this linkage in breeding programs to increase yield will depend on the heterogeneity of the germ plasm between parents in the $\frac{Rs}{rS}$ segment and the effect of other environments on the expression of the yield factor.

SUMMARY

This paper deals with the genetic study of an association of semi-smooth awns and high yield previously reported by Suneson *et al.* (12). With early plantings, the yield increase varied from 14 to 32% of the yield of Atlas, whereas with late plantings there was no noticeable increase.

Linked factors rather than pleiotropic action of the semi-smooth gene (*r*) itself accounted for this association. The gene or genes conditioning the yield increase were found to be located between the *Rr* and *Ss* loci of chromosome V, closely linked with the *Rr* alleles.

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Notes

A COMPARISON OF GREENHOUSE AND FIELD INOCULATION OF LADINO CLOVER WITH *Sclerotinia trifoliorum*[1]

IN A recent paper, Hanson *et al.*[2] describe greenhouse inoculation techniques used to isolate Ladino clover plants resistant to *Sclerotinia trifoliorum* Erikss.. In these greenhouse studies, seedlings and cuttings were grown in flats and inoculated with liberal quantities of dried grain inoculum,[3] when the plants had developed four or five fully expanded leaves. The inoculated plants were placed in a moist chamber maintained at 15 to 20° C. and readings were taken over a 7 to 14 day period. Significant differences in survival were found among strains and clones. The inoculation of seedling progenies from crosses among clones arbitrarily classified as "resistant" and "susceptible" on the basis of survival among vegetative progenies, showed that certain plants were capable of transmitting a reasonably high degree of resistance to their progenies.

A selected group of single cross progenies evaluated in the greenhouse were planted in the field, and inoculated with *S. trifoliorum,* (a) to determine whether or not the level of resistance established in greenhouse tests would be of economic significance under field conditions, and (b) to compare greenhouse and field response. The greenhouse ratings (percentage of healthy survivors) for the progenies included in the field experiment were as follows: 24 resistant × resistant progenies, 24.3%; 22 resistant × susceptible progenies, 15.3%; and 29 susceptible × susceptible progenies, 11.0%.

The 75 single cross progenies were planted in 5 by 10 foot plots in a complete block experiment with 4 replications. Each replication contained five plots of a commercial Ladino clover check. The seed was scarified, planted in vermiculite and subsequently transplanted to flats. Each flat containing 50 seedlings, corresponded to one field plot. The plants were set out in the late spring of 1952 on 1-foot centers within plots. Estimates of percentage ground cover were taken on individual plots on Nov. 22, 1952. The first, third and fourth replicates were inoculated with a broadcast application of dried grain inoculum on Dec. 15, 1952. The inoculum was applied at the rate of 1 g. per square foot. Ground cover estimates were repeated on April 8, 1953, and observations continued through the summer.

A measure of winter killing was obtained from ground cover estimates taken in the uninoculated second replication. The percentage ground cover was 70.2% in November and 60.1% in April, giving a survival rating of 85.6%. The correlation coefficient for fall and spring ground cover estimates in the second replication was highly significant ($r = 0.85$).

There were no significant differences among November ground cover estimates in the three inoculated replications. The effectiveness of artificial inoculation was adequately demonstrated, however, by an average spring survival of 21.5%. An analysis of variance of the inoculated series showed that survival in 42 of the single cross progenies was significantly higher than the commercial check. The differences for 31 of these comparisons were highly significant. None of the single cross progenies had a significantly lower survival than commercial. The survival percentages for one of the better clones were 28.0, 31.0, 39.7, 42.7, 48.7, and 57.3 when crossed with "resistant" clones, and 23.0, 30.7, 37.3, 46.3, and 53.7 in crosses with "susceptible" clones. These survival values contrast sharply with the average survival of all single cross progenies (22.1%) and that of the commercial check (12.5%).

The average percentage of healthy plants in the greenhouse progeny tests was significantly correlated with the percentage field survival ($r = 0.49$). The low predictive value of this association is indicated by the fact that there was no appreciable difference among the average field survival of resistant × resistant, resistant × susceptible and susceptible × susceptible progenies. Inspection of the data showed that several poor greenhouse progenies were good in the field and vice versa. One clone (494–6) classed as susceptible in repeated clonal tests accounted for much of this discrepancy. If clone 494–6 had been classed as "resistant" the average percentage of healthy plants assigned to the three categories in the greenhouse progeny tests would have changed very little (resistant × resistant—22.5%; resistant × susceptible—13.6%; susceptible × susceptible—11.1%).

The results obtained in this experiment show that field survival of some single cross progenies following inoculation with *S. trifoliorum* was sufficiently better than commercial Ladino clover to be of economic significance. Although greenhouse inoculations were effective in isolating some superior plants, the field results show very clearly the difficulty in relying exclusively on greenhouse inoculations. Errors in classification as a consequence of repeated clonal testing could be attributed in part to the decline in vigor which frequently accompanies successive vegetative

[1] Contribution No. 143 of the U.S. Regional Pasture Research Laboratory, Field Crops Research Branch, A.R.S., U.S.D.A., University Park, Pa., in cooperation with the twelve Northeastern States. Received for publication Jan. 21, 1955.

[2] Hanson, A. A., Graham, J. H. and Kreitlow, K. W. The isolation of Ladino clover plants resistant to *Sclerotinia trifoliorum.* Can. Jour. Agr. Sci. 33:84–90. 1953.

[3] Kreitlow, K. W. Infection studies with dried grain inoculum of *Sclerotinia trifoliorum.* Phytopath. 51:553–558. 1951.

increases. The accumulation of virus diseases probably contributes to this decline in vigor.

The excellent field survival of some resistant × susceptible and susceptible × susceptible progenies suggests that errors probably did occur in the greenhouse classification of clones. In addition, the relatively low level of survival in greenhouse tests makes it rather difficult to detect possible errors on the basis of progeny tests conducted under controlled conditions in the greenhouse. The interaction between "winter injury" and Sclerotinia crown rot is another factor which may have contributed to the low predictive value of the greenhouse tests. In this experiment it appeared that Sclerotinia crown rot and winter injury were independent, but there was no method of establishing this fact from the limited data available. In any event, clones and progenies differ in winter survival in the absence of disease and some measure of this response must be obtained in the breeding program. Further studies will be required to determine the degree to which winter injury predisposes plants to Sclerotinia crown rot and vice versa.

Hanson *et al.*[1] concluded that greenhouse tests could be used to screen clones isolated from field inoculation studies. Clones selected on the basis of a replicated greenhouse test would then be intercrossed and their progenies compared in greenhouse trials. The data obtained in this experiment suggest that greenhouse tests might be confined to checking the response of plants isolated from field inoculation trials. Progenies produced from the resulting survivors should be inoculated in the field. — A. A. HANSON *and* J. H. GRAHAM, *formerly Agronomist, U.S. Regional Pasture Research Laboratory, now Research Agronomist, Beltsville, Md.; and Pathologist, respectively.*

[1] *Op. cit.*

Avena sativa L., PROBABLY OF ASIATIC ORIGIN[1]

THE origin of oats, *Avena sativa* L., like that of most leading, cultivated crops, is shrouded in mystery and their migration to Europe is unexplained. Specimen relics of the Bronze and Iron ages reveal that the ancients knew oats. Zade (8), Malzew (4), and others cite Theophrastus, Cato, Varro, Cicero, Ovid, and Virgil who mentioned oats as a weed having medicinal value, whereas writers of the early Christian era, Pliny, Columella, Dioscorides, Galen, and others, list oats of the *A. sativa* type as being grown for food in Europe and those of *A. byzantina* K. Koch as a feed for horses and asses in the eastern Mediterranean and Mesopotamia regions.

The origin of hexaploid ($21n$) chromosome oats is generally accepted as having taken place in Asia Minor or Southwestern Asia, and Vavilov (7) reported finding *A. sativa, A. fatua, A. sterilis* and *A. byzantina* all growing wild in the region. The question "when, by whom and why" were *A. sativa* oats brought into Europe was never answered. History reveals that Slavonic peoples from Asia overran Europe until 451 A.D. when Attila and his Huns were defeated at Châlons-sur-Marne. Logically, Slavonic migrants from Asia Minor may well have carried seed oats from Southwestern Asia or Asia Minor for growing for human food, fodder for horses, or medicinal purposes. Such oats most likely were mixtures or of *A. byzantina* derivation, the type reportedly grown east of the Mediterranean. Information assembled previously by Coffman indicated that *A. sativa* oats probably were derived from *A. byzantina*, a species shown by Shultz (5, 6) and Coffman (1, 2) to be characterized by genetic instability and producing "sativa like" forms. The latter indicated that *A. fatua*, thought by some to be the progenitor of *A. sativa*, possibly arose in a manner similar to the fatuoids found most numerously in certain *A. byzantina* varieties. *A. fatua* was rejected as the probable progenitor of *A. sativa* partly because so far as known that species is in general almost entirely lacking in disease resistance present in many *A. byzantina* and *A. sativa* varieties and in *A. sterilis*.

A. byzantina, being polymorphous when taken from Southern Asia to the colder temperatures of Europe would permit the elimination of "heat tolerant types" and the ascendency of the "sativa like" derivatives adapted to cool temperature. In North America such a transition took place in the origin of Fulghum, an "intermediate type" from Red Rustproof, and in turn of Columbia, a still more "sativa like" oat as a selection from Fulghum. Fulghum is adapted farther north than Red Rustproof, and Columbia to the north of Fulghum's area of adaptation. Since this occurred in much less than a century, greater transitions could have occurred in 30 centuries or longer. Thus a plausible explanation for the development of *A. sativa* in Europe is apparent.

The belief of the ancients that oats had medicinal properties may have resulted from the apparent potency of sprouted oats in inducing fecundity and virility in Mammalia. Graves (3) indicates this to be a new discovery. Possibly the antiquity of the expression that the "horse feels his oats" is little realized.

It is postulated that *A. sativa* arose from polymorphous *A. byzantina* oats taken into Europe by Slavonic migrants from Asia Minor. This seems more logical than the previously held theory that it arose by mutation from *A. fatua*. — FRANKLIN A. COFFMAN, *Senior Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A.*

[1] Received for publication Feb. 5, 1955.

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A FOUR-ROW, V-BELT NURSERY SEEDER[1]

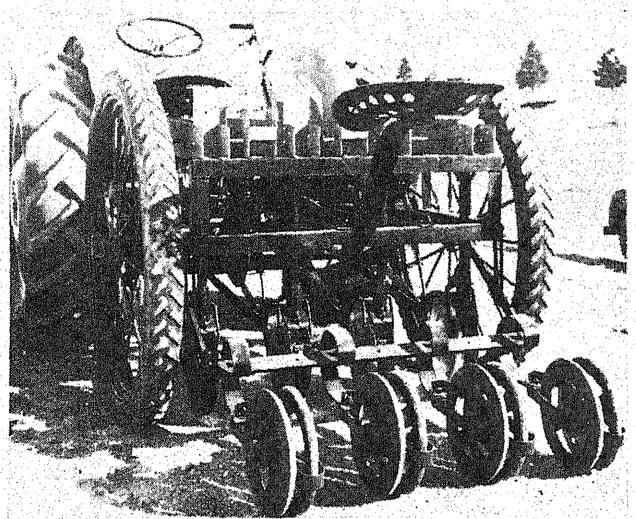

FIG. 1.—General view of nursery planter.

NURSERY seeders have been built by many plant breeders in recent years and several descriptions published (1, 2, 3, 4, 5, 6).

Dry top-soil conditions at planting time for winter wheat and winter barley are common in the Hays, Kans., area. Little rain can be expected, and rapid drying of the top soil usually follows any precipitation received. Such conditions are not conducive to good emergence and good stands of small grains with the result that stands are often spotty and emergence uneven. Winterkilling and wind erosion are also common. To surmount these conditions, it appeared necessary to devise equipment capable of planting a number of different types of seed at depths where moisture could be reached while maintaining other conditions favorable for emergence.

A mounted planter with hydraulic lift for turning or backing was built by John J. Burkhart, Jr., station shop foreman, using standard drill parts where possible. V-belts, frames, and windshields were brought from Vulcan Iron and Engineering, Ltd., Winnipeg. Other parts were produced in the station machine shop.

As shown in figure 1, the planter has four V-belts mounted in regular V-belt frames, which also support windshields if needed (figure 2). The belts run on concave pulleys mounted individually in front so they may be loosened when not in use. Power is applied by a system of gears to the rear pulleys, which are all on the same shaft. The main drive gear is mounted on the axle. It consists of a gear assembly from a McCormick drill and is conical in shape with 10 rows of cogs (figure 3). A sliding gear can be engaged in any desired row of cogs on this conical gear. The sliding gear transmits power to another gear system that has a sprocket, available in three sizes. This sprocket transmits power by a chain drive to the shaft on which the rear pulleys are mounted and on which the V-belts turn. A total of 10 belt speeds is available. By changing sprockets, the number can be increased to 30. With the large sprocket the belt travels from about 8 to 50 feet varying with the row of cogs, with one filling of seed. Longer rows are obtained by using smaller sprocket gears. An idler gear is required to reverse the direction the belt travels so that seed drops off the rear of the belt.

Seed tubes and double-disc furrow openers are from a regular, field-size McCormick grain drill (figure 3). These furrow openers are under adjustable spring tension to control penetration in the soil. The depth of planting is further

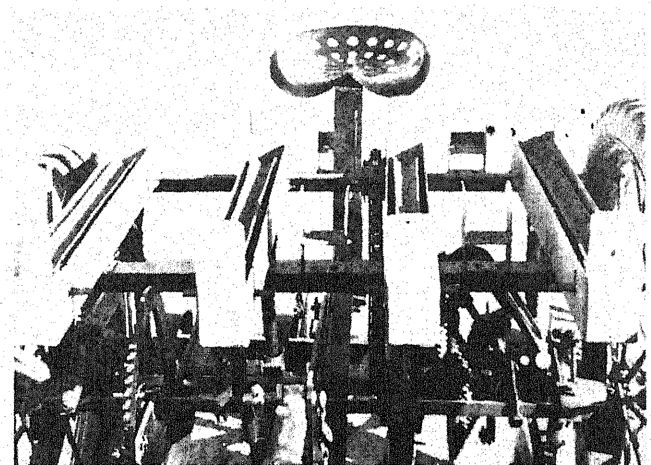

FIG. 2.—Nursery planter showing arrangements of V-belts and seed trays. Note also the gear system used to drive V-belts.

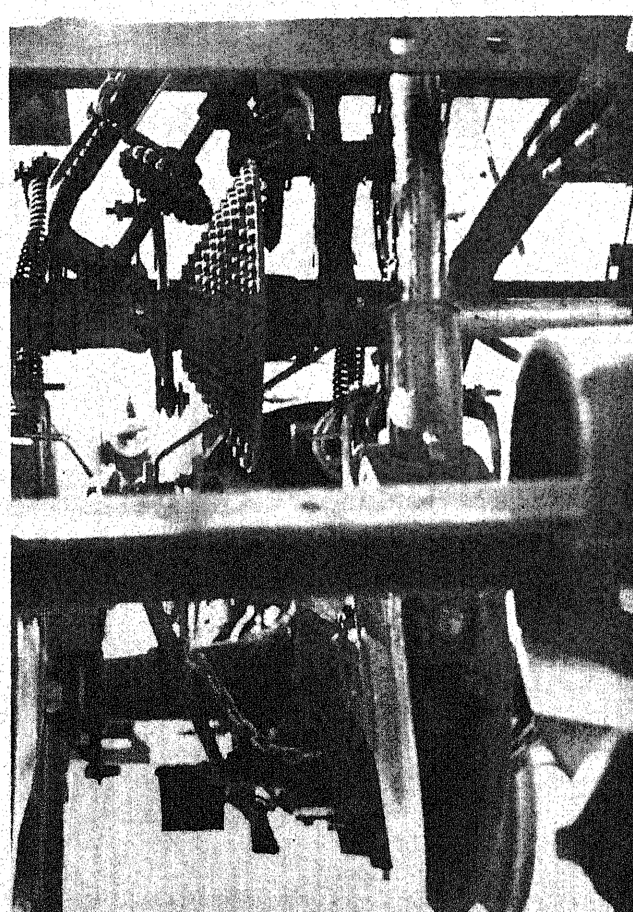

FIG. 3.—Nursery planter showing gear system, furrow openers and seed spouts.

[1] Contribution No. 89, Fort Hays Branch, Kansas Agr. Exp. Sta. Received for publication Feb. 7, 1955.

controlled by a lever connected to the shaft on which the double-discs are mounted. Pack wheels are of the open-center type.

A rigid three-point linkage to a tractor is used.

The planter operator sits on an implement seat while spreading seed, or, if two operators are available, they stand on the framework supporting the pack wheels (figure 1). A seat for two operators could be added. Racks for two seed trays are mounted beside the V-belt frames.

Rows are planted to the middle of the alley where the tractor is stopped, the belts cleaned, and new seed spread. One planter operator can plant per day 2,000 to 2,500 or more rows which are trimmed to 8 feet at harvest; two operators double this rate. In practice the machine has been found practical for seeding all types of yield and breeding plots at a rate double or more that of a hand-operated V-belt. As good or better stands as with a field drill have been obtained where moisture was at all favorable.—JOHN D. MILLER, *Assistant Professor, Fort Hays Branch of the Kansas Agr. Exp. Sta., Hays, Kans., and* W. M. ROSS, *Associate Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A.*

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BREEDING FOR RESISTANCE TO YELLOW DWARF VIRUS IN BARLEY[1]

THE yellow dwarf virus disease has probably reduced yield of barley, wheat, and oats in California by more than any of the other cereal crop diseases in each year since its discovery in 1951. This virus, its general effect, its vectors, and its host range have been recorded.[2] Because of its economic importance, and the likely importance of breeding for its control, this report on the nature and on the inheritance of a "resistance" difference seems timely.

The resistance of the Rojo variety and of a few F_2 segregates from a Rojo × California Mariout[3] backcross was first observed in 1951. It was recognized then that some other varieties possessed a higher level of resistance than Rojo, but that no other breeding material could be adapted for wide use against this virus as quickly as this backcross population.

Since this was a new disease, appropriate testing and evaluation technics had to be developed. In estimating comparative injury from yellow dwarf on a 0 to 4 scale, Rojo has generally been assigned a value of 1 and California Mariout a value of 3. In plant or population assays under common growth stage and natural mass infection synchronizations this range translates into a 10 to 35% yield difference. This varietal difference is distinct from the actual yield level where time (duration) of infection is singularly important. Thus in California Mariout a near lethal reaction results from seedling stage infection, but this is an unlikely event under normal cropping conditions.

During 1952 and 1953 the levels of persistent yellow dwarf infection were not sufficient for precise plant classification, but with information integration resistant lines were successfully advanced. The dominance of susceptibility was established. In 1954 a backcross population, the equivalent of 895 F_2 plants derived from 12 parental lines proven equivalent to Rojo in resistance, was classified. This population divided distinctly into three classes: 641 susceptible, 209 resistant, and 45 escaping infection. This clearly indicates a single recessive gene difference between Rojo and California Mariout. Since this gene, after four backcrosses, is now set in plants predominantly like California Mariout, it seems destined for early use to reduce yield losses from yellow dwarf in the extensive areas where this variety is adapted. — COIT A. SUNESON, *Research Agronomist, Field Crops Branch, A.R.S., U.S.D.A. and Department of Agronomy, Univ. of California, cooperating.*

[1] Received for publication Feb. 28, 1955.

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Book Reviews

FARM EQUIPMENT AND MACHINERY, 4TH EDITION

By Harris Pearson Smith. New York. McGraw-Hill Book Co. 514 pp. 1955. $7.50.

All types of farm equipment for field crops are discussed in this complete revision of the author's well known work. In addition to tillage and planting equipment, the author includes equipment for application of herbicides and insecticides. Among the new chapters are those on power lift controls, lubrication (which gives the American Petroleum Institute's new classification of engine oils), and application of liquid and gas fertilizers. Separate chapters are presented on primary and secondary tillage equipment, and on power lifts, and rubber tires, weed control, spraying and dusting, fertilizers, hay and forage, grain, cotton, processing equipment, and miscellaneous harvesters. The agricultural engineering students will find this a complete, up-to-date treatment of the field, and farmers and farm advisers can use it as a reliable reference work. The author is at Texas A&M college.

METHODS OF PLANT BREEDING, 2ND EDITION

By Herbert Kendall Hayes, Forrest Rhinehart Immer, and David C. Smith. New York. McGraw-Hill. 551 pp. 1955. $8.50.

In this revision, the authors have added much of the new knowledge in the plant breeding sciences which has accumulated since 1942 when the first edition was published. They have placed special emphasis on the following: centers of origin of crop plants, heterosis, breeding for insect resistance, the breeding of cotton and sorghum as representatives of crops often cross pollinated, and a review of the present viewpoint of forage crop breeding.

Chapter headings include: Heterosis, The Role of Plant Breeding Techniques in Selfing and Crossing, The Pure-line Method of Breeding Naturally Self-pollinated Plants, Hybridization as a Method of Improving Self-fertilized Plants; The Backcross Method; Breeding for Disease and Insect Resistance; Special Techniques; Inheritance of Small Grains and Flax, Cotton and Sorghum Breeding; Development of Methods of Corn Breeding, Inheritance in Maize; Forage-crop Improvement.

Separate chapters are included on correlation and regression, Chi-square tests, field-plot technique, experimental designs, and heritability. An excellent glossary of close to 200 terms is included as well as an appendix of 6 tables for statistical analysis reprinted from other sources.

LAND JUDGING

By Edd Roberts. Norman, Okla. The University of Oklahoma Press. 120 pp. 1955. $2.50.

The author, one of the pioneers in land judging contests at Oklahoma A & M College, is well qualified to prepare a handbook for this method of soil evaluation. The six short chapters are exceptionally well written, clear and to the point, and the illustrations are well chosen. The chapters tell how to judge land by physical characteristics and soil tests and classifications, how to use the land-judging score card, and how to go about conducting and implementing a land-judging contest. After supervisinig more than 300 land-judging contests in which more than 60,000 individuals participated, Mr. Roberts is a zealous promoter of the contests as an effective means to promote a better understanding and use of our soils. As a parallel he cites the growth of livestock judging and the benefits to agriculture which have been derived therefrom. Land judging, he rightly maintains, is perhaps a more fundamental activity than livestock judging. This manual is certain to be widely used.

ANALYSIS OF SOILS AND PLANTS FOR FORESTERS AND HORTICULTURISTS

By S. A. Wilde and G. K. Voigt. Ann Arbor, Mich. J. W. Edwards. 117 pp. 1955. $3.75.

"Diagnosis of soil productivity by field and laboratory methods" is the subtitle of this pioneer work which comes to grips with the particular problems of fertility in soils which support woody plants—forest and orchard trees. The great majority of published reports on soil fertility in the past 25 to 30 years is based on investigations in field crop culture. Many of the special problems in soils which support trees and shrubs remain unsolved. This book presents various tests and techniques designed specifically for these soils. It is divided into 7 main parts: analysis of physical properties of soils; analysis of chemical characteristics of soils; analysis of ground water; analysis of biological and microbiological properties, of soils, organic residues, and composts; floristic and mensuration analyses of native vegetative cover; chemical analysis of plant tissues; and determination of morphological and physiological characteristics of nursery stock.

The authors place special emphasis on the technique of soil sampling required for determining the different soil characteristics, and the relative value of various analytical procedures as applied to soils supporting woody plants.

There are four appendices: notes pertinent to chemical analysis of soils, soil fertility standards for raising nursery stock and critical content of nutrients in soils of planting sites; conversion factors commonly used in soil and timber analyses, and international atomic weights of elements important in soil analyses. With the exception of a sizeable list of errata, the book is a good example of the "offset" printing process. It is dedicated to Emil Truog, emeritus professor of soils at the University of Wisconsin.

VEGETABLE PRODUCTION AND MARKETING

By Paul Work and John Carew. John Wiley & Sons. 536 pp. 1955. $4.72.

Home gardeners and farmers as well as the college student will find much of value in this introduction to vegetable production and marketing. As a text book, it is designed for use along with class trips, field surveys and home projects. For the student, the authors have placed special emphasis on inherited characteristics of crop plants and their responses to environment. The problems of commercial farm management and produce marketing are well presented, and the book on the whole, in addition, is well suited as a reference for the amateur gardener. It contains 12 chapters on principal crops and crop groups. The chapter which discusses plant growth, physiology, photosynthesis, respiration, reproduction and breeding, seems particularly well written for any of the potential users of the book. The same can be said for the discussions on soil management, disease and insect control, and seed. Extensive references are listed following each chapter, and the book is adequately illustrated. The authors are at Cornell University.

SOIL AND WATER CONSERVATION ENGINEERING

By Richard K. Frevert, Glenn O. Schwab, Talcott W. Edminster, and Kenneth K. Barnes. New York. John Wiley & Sons. 479 pp. 1955. $8.50.

This welcome book presents an integrated treatment of all aspects of soil and water conservation from the standpoint of the engineer. It is the first such attempt to cover the subject in this manner, and the authors deserve commendation for developing a textbook for agricultural engineering students who can, with the help of this book, survey this broad field and not miss any of the opportunities which it offers and the problems which it meets. Following general chapters on the scope of the subject, and on hydrology and physics, chapters 6 to 22 cover wind erosion, contouring, strip cropping, terracing, reservoirs, embankments, headwater control, field surface and subsurface drainage, earth dams, land clearing, etc. An especially helpful appendix includes U. S. rainfall maps, methods of runoff determination, Manning velocity formula, pipe and conduit flow, drain tile specifications, earth moving rates, loads on underground conduits, conversion constants, gravel filters, volume formula and layout of circular curves. With the exception of Mr. Edminister, who is with the USDA, the authors are on the Iowa State College Staff.

PESTICIDE HANDBOOK

By D. E. H. Frear. College Science Publishers, State College, Pa. 7th edition. 208 pp. 1955. (paper bound, $1.25; cloth bound, $3.00).

The product listings in this year's handbook include 6,204 items, covering insecticides, fungicides, herbicides, rodenticides, and soil conditioners, as well as equipment. The products are listed

under their trade names in the first section of the handbook, while in the second section the chemical materials used in the various pesticides are given. A coding system makes it possible for the reader to find all commercial products in which each chemical is used. The book also includes the names of pesticide manufacturers and of professional pest control operators.

PLANTS WITHOUT FLOWERS

By Harold Bastin. New York. Philosophical Library. 146 pp. 1955. $6.00.

The vast—and to many, mysterious—world of flowerless plants is vividly portrayed in this beautifully executed work. A competent knowledge of the field is coupled with a skillful style to introduce to the student or the lay reader the varied forms of plant life from which mankind has derived beauty, pleasure, and health, as well as no small amount of suffering and disease. Mr. Bastin presents separate chapters on slime fungi, algae, lichens, the true fungi, mosses and liverworts, ferns, fern allies, horse tails, and club mosses. Bacteria are included in the chapter on slime fungi, and due recognition is given the role which saprophytes play in nitrification of soil. Of the greatest interest to a general reader is perhaps the chapter of true fungi, for considerable discussion is given to the field crop, fruit, and vegetable diseases, skin infections and other diseases caused by fungi. Excellent photographs are grouped together in a central section of the book, and line drawings are used liberally to complement the clearly written text. A glossary of more than 500 plant names, with the Latin classification, is also included. Only the common names are used, however, in the text.

OAT IDENTIFICATION AND CLASSIFICATION (U.S.D.A. Technical Bulletin No. 1100)

By T. R. Stanton. Washington, D. C., U. S. Govt. Printing Office. 206 pp. April 1955. $1.50.

This bulletin presents the description, history, distribution, and synonomy of the botanical and agricultural varieties of oats grown commercially. It also describes certain varieties of known, or potential, plant breeding and taxonomic value which are grown and recognized primarily by experiment stations and other research institutions. The bulletin was written in response to a demand for a classification that considers agronomic, physiologic, and pathologic characters as well as the purely botanical characters for the identification of oat varieties; it is the former which determine the extent of the culture and distribution of a variety, as well as aid in its identification. Characters described are morphological, stem, leaf, panicle, spikelet, lemma, awn, caryopsis, and physiological. Species and subspecies include large naked, small naked, wild red, red, desert, slender, sand, Abyssinian, short, wild, and common.

HANDBOOK OF FOOD AND AGRICULTURE

Edited by Fred C. Blanck. New York. Reinhold Publishing Co., London, Chapman and Hall, Ltd. 1038 pp. 1955. $12.50.

Twenty-nine specialists from as many fields have contributed to this monumental work which summarizes the latest knowledge in selected areas of agricultural production and food technology and processing. The 26 chapters cover such diverse yet closely related topics as soils and plant growth, fertilizers, insecticides and herbicides, human nutrition, storage of raw products, food processing and preservation, packaging, waste disposal, growth regulators, enzymes, dairy products, vegetable fats and oils, animal products, and sea foods.

Although one might consider it difficult to present comprehensive summaries on such a wide array of topics in one book, the chapters on Soils by Eric Winters, Soil Fertility by C. L. W. Swanson, Fertilizers by A. L. Mehring and Soil Microbiology, by Charles Thom indicate how thoroughly the subjects are covered. The soils chapter covers physical, chemical, colloidal, and biological properties, exchangeable cations, hydrogen ion concentration, structure control, moisture control, and classification and geography. A. L. Mehring discusses the composition and properties of animal manures, sewage sludge, compost, peat, seaweed, liming materials, and commercial fertilizers. Dr. Swanson discusses fertility and productivity, soil and plant fertility relationships, pH and nutrient availability, and the availability, interactions, and utilization of each of the major and minor elements.

The book is well illustrated, tables are numerous, and each chapter is documented. Dr. Blanck is a former soil scientist with the USDA who retired in 1952 from the H. J. Heinz Co. where he served as chief research chemist and later with the company's Mellon Institute.

Agronomic Affairs

MEETINGS

June 25–27, American Society of Commercial Seed Technologists, Stillwater, Okla.
June 27–29, North Central Branch, A.S.A., Iowa State College, Ames.
June 27–30, Association of Official Seed Analysts, Stillwater, Okla.
June 28–30, Pacific Northwest Regional Fertilizer Conference, Boise, Idaho.
July 7, Summer meeting, Miss. Section A.S.A. Coastal Plain Exp. Sta., Newton, Miss.
July 18–19, Eighth biennial Eastern Alfalfa Improvement Conference, Cornell University, Ithaca, N.Y.
July 21–22, Great Plains Agricultural Ammonia Trade Show and Field Day, Des Moines and Ames, Iowa.
July 25–28, Northeast Branch, American Society of Agronomy, Pennsylvania State University.
Aug. 1–6, 3rd International Congress of Biochemistry, Brussells, Belgium.
Aug. 15–19, American Society of Agronomy and Soil Science Society of America, University of California College of Agriculture, Davis.
Aug. 29–Sept. 6, International Horticultural Congress, Scheveningen, Holland.
Sept. 7–9, American Society for Horticultural Science, Michigan State University, East Lansing, Mich.

NORTHEAST BRANCH MEETING WILL PARTICIPATE IN JORDAN FERTILITY PLOT ANNIVERSARY

The 1955 annual meeting of the Northeastern Branch, American Society of Agronomy, will be held jointly with the 75th anniversary of the Jordan soil fertility plots July 25–28 at Pennsylvania State University. The Jordan plot celebration will be held Tuesday, July 26, with a special afternoon program and a memorial banquet in the evening.

Registration and assignment of lodgings will be held in the lobby of McElwain hall beginning at 2 p.m. on Sunday, July 24.

The Northeastern section's business meeting will be held at 7:30 p.m. Tuesday, July 25 in the Hetzel Union building.

Visits to local farms and inspection of highway shoulder and slope revegetation and forage breeding nurseries are planned for Monday morning. Monday afternoon tours are as follows: Soil mineralogy, C. D. JEFFRIES; soil testing lab, R. J. THOMAS; greenhouse research on soil root relations, D. P. SATCHELL; U. S. pasture research laboratory, R. J. GARBER, R. R. ROBINSON, V. SPRAGUE, and J. T. SULLIVAN; potato breeding, W. R. MILLS; potato variety tests, J. S. COBB.

Tours of Jordan fertility plots will be held Tuesday morning with A. C. RICHER, R. J. GARBER, H. L. CARNAHAN, J. H. GRAHAM, S. M. RALEIGH, and L. T. KARDOS. Speakers at the Jordan celebration program Tuesday afternoon include Profs. F. J. HOLBEN, J. W. WHITE, A. C. RICHER, C. D. JEFFRIES, H. W. HIGBEE, and F. G. MERKLE.

Dean L. E. JACKSON of the Pennsylvania College of Agriculture will preside at the Jordan Memorial banquet Tuesday evening. Guest speaker will be Dean W. I. MYERS of the College of Agriculture, Cornell University.

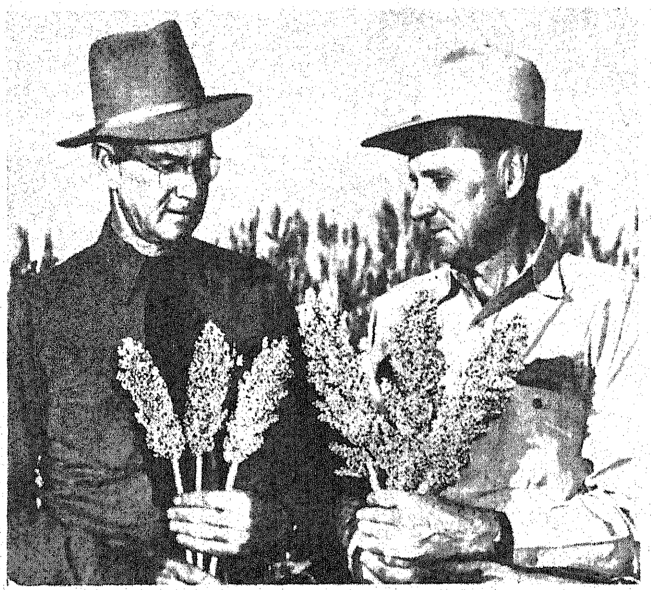
H. R. ALBRECHT, director of agricultural extension at Pennsylvania State University, will preside at the Wednesday morning session of the Jordan plot celebration. F. E. BEAR, former head of the soils department, Rutgers University; EMIL TRUOG, former head of the soils department, University of Wisconsin; and C. E. MILLER, of Michigan State University will take part in a discussion on the contribution of long-term soil experiments to practical agriculture, research, and teaching.

Tours on Wednesday include special turf experiments, H. B. MUSSER; corn breeding, L. L. HUBER; corn genetics, J. E. WRIGHT, JR., small grains, C. S. BRYNER; Foundation Seed project, G. W. MCKEE, R. C. WALKER; breeding for disease resistance in corn, C. C. WERNHAM; and forage management field experiments, J. B. WASHKO.

Special tours to outlying experiments on July 28 will be conducted by B. F. COON, L. L. HUBER, L. T. KARDOS, J. B. WASHKO, H. W. HIGBEE, and A. E. COOPER.

Special features are planned for women.

SOCIETY MEMBERS WIN HOBLITZELLE AWARDS



J. Roy Quinby (left) and Joseph C. Stevens

Three members of the American Society of Agronomy received the 1955 Hoblitzelle Agricultural Awards announced in May. STERLING R. OLSEN, USDA soil scientist with the Colorado Agricultural Experiment Station, Fort Collins, won the award in agricultural sciences for development of a sodium bicarbonate method for estimating available soil phosphorus. He received \$5,000 and a gold medal. J. ROY QUINBY, superintendent of the Texas Branch Station at Chillicothe, and JOSEPH C. STEPHENS, USDA plant breeder at the Chillicothe branch station, jointly received the award for advancement of Texas rural life for their development of a practical method for commercial production of hybrid sorghum seed. They shared a \$5,000 cash award, and each received a gold medal.

Olsen

Dr. Olsen has been with the USDA since 1945 and at Fort Collins, Colo., since 1948. Quinby and Stephens have both been engaged in research at Chillicothe since 1925.

IOWA PLANS FULL PROGRAM FOR NORTH CENTRAL MEETING

The agronomy department of Iowa State College has planned a full and varied program for the 1955 meeting of the North Central Branch, American Society of Agronomy at Ames, June 26–29.

Registration will take place from 2–10 p.m. Sunday, June 26 in the College Memorial Union, and from 8–9 a.m. Monday, June 27. The Monday morning program will be devoted to summaries of current research and teaching programs at Iowa State College presented by W. H. PIERRE, F. F. RIECKEN, R. H. SHAW, I. J. JOHNSON, J. L. ROBINSON, B. J. FIRKINS, R. R. KALTON and E. R. DUNCAN.

Following two general tours Monday afternoon, special interest tours are planned as follows: plant industry station, M. M. HOOVER; soil conditioner and ridge-row planting plots, DON KIRKHAM and W. F. BUCHELE; turf plots, H. L. LANTZ; weed control in soybeans and corn; D. W. STANIFORTH and C. R. WEBER; rotation-fertility plots, W. D. SHRADER, A. ENGLEHORN, and J. PESEK; soil judging, F. W. SCHALLER; equipment, machinery, and weather station, H. MELDRUM, R. E. ATKINS, and R. SHAW.

M. A. ANDERSON, associate director of Agricultural Extension Service, will preside at the Monday evening meeting at which E. R. DUNCAN, E. O. HEADY, J. PESEK, and I. J. JOHNSON will speak.

Tuesday's tour of small grain nurseries will be conducted by the following: R. E. ATKINS and K. J. FREY, S. C. WIGGANS, R. M. LEWIS, J. A. BROWNING, and M. D. SIMONS.

C. P. WILSIE, JOHN BAXTER, and R. R. KALTON will explain current work on forage crop breeding.

Three meetings are planned for Tuesday morning as follows: Session 1.—Tillage and intercropping practice in corn production with G. M. BROWNING, R. L. COOK (Michigan State College), W. E. LARSON, W. F. BUCHELE, F. W. SCHALLER, C. A. VAN DOREN, and H. B. ATKINSON (University of Illinois); Session 2.—Soil physical properties and crop growth, D. KIRKHAM, presiding, with M. B. RUSSELL (University of Illinois), G. S. TAYLOR (Ohio State University), A. E. ERICKSON (Michigan State College), S. W. MELSTED (University of Illinois), R. E. DUNCAN (Iowa State College) and C. M. WOODRUFF (University of Missouri). Session 3.—Research in soil fertility and management in Iowa, with J. T. PESEK, W. D. SHRADER, JOHN WEBB, LLOYD DUMENIL and JOHN HANWAY.

Tuesday afternoon meetings include: nitrogen in Midwest agriculture; pasture and forage evaluation; rainfall-soil-crop relationships, and regional soil profile monoliths. Tuesday conferences are scheduled for pasture research, potassium soil tests, soil moisture and temperature survey, and deep tillage and fertilization research. General sessions on Wednesday morning are devoted to crops, soils, and nitrogen soil testing. Tours to 4 outlying experimental fields are planned for Wednesday also.

COMMUNICATIONS

MUTATIONS BY ELECTRIC CURRENT

Dr. W. Ralph Singleton's most interesting paper on the "Contribution of Radiation Genetics to Agriculture" deserved top-billing in your March 1955 isue of *Agronomy Journal*. He apparently confined his review of the early literature on the subject to the X-ray technique. In my reading on this general subject I have come across a very informative treatise on the mutation of botanical species by means of the electric current. The work was by Alberto Pirovano and the complete study was published in Milano, Italy in 1922 with the title—

> "La Mutazione elettrica delle
> specie botaniche e la disciplina
> dell' eredita nell'ibridazione"

Pirovano states that he started his studies in 1899. Undoubtedly copies can be located in some of our technical libraries. I have a copy in my library.

This treatise should be known by American workers in the field of genetics. It is complete and well illustrated. Although Dr. Singleton states that radiation genetics had its origin in fundamental researches conducted by Dr. H. J. Muller and Dr. L. J. Stadler in 1927 and 1928, this work shows that Pirovano preceded these other scientists by many years. Pirovano used X-rays in addition to the electro magnetic field in bringing about genetic mutations.

V. SAUCHELLI

The Davison Chemical Corp.
Baltimore 3, Maryland

INTERNATIONAL ARID LANDS MEETINGS

More than 400 delegates from 24 countries met in New Mexico April 26 to May 4 in the International Arid Lands Meetings. The meetings were sponsored by the American Association for the advancement of Science and its Southwestern and Rocky Mountain Division.

The first 4 days of meetings at the University of New Mexico in Albuquerque consisted of open meetings and discussions. Field trips into surrounding desert areas were held on April 30 and May 1. A similar group met by invitation at the New Mexico Institute of Mining and Technology at Socorro, N. Mex., on May 2 to 4 to discuss and work out ways for better cooperation in solving arid land problems.

The speakers emphasized that only a small part of the potential of arid lands is being utilized. Animal life is only partly utilized and plant breeding and better management practices can give more efficient use of present water resources. The discussants agreed that cloud seedings had definitely increased rainfall. But the effectiveness of silver iodide burners was held to be small unless the discharge is made from high mountain peaks or from airplanes directly into cloud formations.

Significant advances have been made in desalting water. Electrolytic removal of salts through selective membranes can reduce salt in water from 4,000 parts per million to 1,000 parts per million for about 8 cents per ton. This is nearing an economic level for irrigating high value crops.

The general consensus seemed to be that better cooperation among research workers of arid lands offers greater hope for solving the important problems than would the establishing of an international research center.—D. W. THORNE.

TWO PROMOTED AT TEXAS A&M

J. B. Page

J. E. Adams

Two top positions on the faculty of the A. and M. College of Texas were filled recently by members of the American Society of Agronomy and Soil Science Society of America. JAMES E. ADAMS, head of the college's coordinated department of Agronomy since 1948, was named Dean of the School of Agriculture April 25. He succeeds CHARLES N. SHEPPARDSON, who has resigned after 11 years as Dean to accept appointment as a member of the Board of Governors of the Federal Reserve System.

Dr. Adams was born on a farm near Lee's Summit, Mo., in 1898, and is a graduate of William Jewell College, Liberty, Mo. He took his M. S. degree from Purdue University in 1922 and his Ph. D. from Iowa State College in 1936.

His successor in the agronomy department is J. B. PAGE. Dr. Page joined the Texas A. and M. agronomy department in 1950 as head of the soil physics section. He received the Stevenson Award of the American Society of Agronomy in 1954. He is a native of Utah, holds a B. S. degree from Brigham Young University, M. A. from the University of Missouri, and Ph. D. from Ohio State University.

DETAILS OF INTERNATIONAL GRASSLAND CONGRESS TO BE PUBLISHED THIS SUMMER

Detailed plans for the 7th International Grassland Congress will appear in a booklet to be published this summer, according to the organizing secretary of the congress. The congress, which will meet at Massey Agricultural Congress, Palmerston North, Nov. 6–15, 1956, is being sponsored by the New Zealand government under auspices of the New Zealand Grassland Association.

The Massey college farms are devoted to dairying on the river flats and to sheep and cattle on the terraces and hill country. Most types of North Island grassland farming are practiced at or near the college. Adjoining the college are the Dairy Research Institute and the Grassland Division of the Department of Scientific and Industrial Research, which is the major grassland and research station in New Zealand.

Registration fee for all persons attending the Congress is 5 Pounds (approximately $14.00) and will entitle registrants to a copy of the Congress proceedings.

A weekend 300-mile tour has been arranged for Nov. 10–11 which will pass through dairying and fat lamb raising country, hill country and tussock grassland. Two other concurrent tours of the North and South Islands, respectively, have been arranged following the Congress proper from Nov. 16–20.

The New Zealand Grassland Association will hold its annual conference at Canterbury College, Lincoln, Nov. 27–29. This meeting will give overseas visitors further opportunity to study New Zealand grassland farming. Canterbury College is the oldest agricultural college in the southern hemisphere.

NORTH CAROLINA HONORS E. E. CLAYTON

Phytopathologist E. E. CLAYTON was honored by North Carolina State College where he was awarded the Doctor of Science Degree during Commencement on May 29. Dr. Clayton, formerly in charge of tobacco breeding and disease work for the USDA, was cited for his outstanding contributions in tobacco breeding and disease research leading directly to the development of disease resistant varieties, which have meant so much to growers and the economic welfare of North Carolina and other tobacco growing states.

Disease resistant varieties which Dr. Clayton has been instrumental in developing, now planted on more than 250,000 acres in North Carolina alone, are returning increased profits to growers of millions of dollars each year. Without these improved tobacco varieties, profitable tobacco production on thousands of disease infested farms would be impossible. On the evening of May 28, prior to Commencement, Dr. and Mrs. Clayton were entertained by friends and co-workers from experimental stations, industry, and farm groups with a banquet on the North Carolina State College Campus.

SOCIETY ISSUES "CAREER" PAMPHLET

"Your Career in Agronomy," a brochure describing job opportunities in agronomy, has just been issued by the American Society of Agronomy. The booklet represents a joint effort of the Agronomic Education Division of the Society and the special Committee for Training Soil Scientists of the Soil Science Society of America.

Single copies are available at no cost from the Society headquarters, 2702 Monroe Street, Madison, Wis., or from agronomy and soils departments throughout the country. Quantity orders are also available to agronomy and soils departments at a rate which covers printing and shipping costs.

The brochure is written primarily for high school students. It was prepared by GLENN KLINGMAN, North Carolina State College; M. B. RUSSELL, University of Illinois; and DARREL METCALFE and LOUIS THOMPSON, both of Iowa State College.

U.S. ENTOMOLOGIST RETIRES

E. L. GRIFFIN retired April 1 as Assistant Head of the Pesticide Regulation Section, Plant Pest Control Branch of the Agricultural Research Service, USDA. Dr. Griffin joined the Department of Agriculture in 1910. Following his retirement at the end of this month, Dr. Griffin will return to his farm four miles north of Lawrence, Kans.

A. F. MILLER RETIRES FROM SWIFT

ARTHUR F. MILLER, of Western Springs, Ill., general manager of the Plant Food division for Swift & Company since 1947, retired on April 1. He is succeeded by WILLIAM F. PRICE, of Hinsdale, Ill., who has been assistant manager of the Plant Food division since 1952.

Miller, a native of Iowa, began his career of 43 years at Swift as secretary to the manager of the Plant Food division. Price joined Swift in 1925 at Calumet City, Ill., as a sales representative for the Plant Food division. He became sales manager of the Pacific coast area with headquarters at Los Angeles in 1929. He later managed plant food factories at Ontario, Calif., and Los Angeles.

COMPLETE SET OF JOURNALS AVAILABLE

The central office of the American Society of Agronomy has one complete set of the *Agronomy Journal*, Vols. 1–46 for sale. The price is $12.00 per volume, the standard back number price. Inquiries may be directed to L. G. MONTHEY, executive secretary, American Society of Agronomy, 2702 Monroe St., Madison 5, Wis.

NEWS NOTES

JOHN L. SANDERS has been appointed sales manager of the Chemical Division of the Mississippi River Fuel Corp., St. Louis, Mo. He had been with the Spencer Chemical Co., at Atlanta, Ga., since 1950.

H. F. RHOADES is again stationed at the University of Nebraska agronomy department after having served for the past several months as assistant head of the Western Soil and Water Management Section, SWCRB, USDA, Beltsville, Md.

—A—

DARCY M. SATER of Yakima, Wash., has been named manager of the seed division of the Chas. H. Lilly Co., of Seattle.

—A—

CHARLES H. KLINE has been appointed manager of the newly-created chemical development division of Climax Molybdenum Co. in New York.

—A—

LAWRENCE ZELENY, chief of the USDA Grain Division Standardization and Testing Branch, is the new president-elect of the American Association of Cereal Chemists.

—A—

ROBERT Q. PARKS has been named general sales manager of Grace Chemical Co. Since joining Grace Chemical in early 1953, Dr. Parks has been serving as manager of agricultural services.

—A—

E. D. WALKER, University of Illinois extension agronomist and soil conservationist, is one of five staff members honored at a special reception May 20. The five will retire this fall.

—A—

RALPH F. CRIM, Minnesota hybrid corn specialist, returned in May from Yugoslavia where he had spent the past year as an advisor with the U. S. operations mission to that country.

—A—

A. B. VERDERY has been appointed eastern district sales manager of the Olin Mathieson Chemical corporation's eastern fertilizer division.

—A—

E. B. REYNOLDS was granted a leave of absence from the Texas A&M college, May 9 to serve as agricultural consultant in Pakistan.

—A—

CARL S. HOVELAND was appointed instructor in agronomy at the University of Florida June 1. He is concerned with pasture research and is also working toward his Ph.D. degree. Until this appointment he was assistant agronomist at the Texas Agricultural Experiment Station, Crystal City, Tex.

—A—

A. W. TAYLOR left the University of Wisconsin June 12 to return to his duties in England where he is a member of the chemistry department staff of Rothamsted Experimental Station at Harpenden. During his 9-month leave at the University of Wisconsin soils department, he completed a study of the composition of solutions in equilibrium with a number of soil samples from experimental plots in Wisconsin.

PERSONNEL SERVICE

The Personnel Service column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of $2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a key number which will be carried for five additional insertions unless a discontinue order is received. Items pertaining to soils positions will be inserted one time in the *Soil Science Society of America Proceedings* unless otherwise specified. The following insertions, published in earlier issues, are still available: 1–1, 2–1, 2–2, 2–3, 4–1, 4–2, 4–3.

POSITION WANTED

Agronomist, M. S. in Agronomy, University of Riga and Academy of Agriculture, Jelgava, Latvia. Employed for past five (5) years with State Seed Testing Laboratory as a seed analyst. Prior work in Latvia, which was disrupted by war activities, include one (1) year with Academy of Agriculture in field crop research and three (3) years with Latvia Department of Agriculture as Agent in charge of seed certification. Forty-five years old, married, one child. Has speaking and reading knowledge of English and German. Desires research, or a combination of research-teaching position, which offers a greater challenge for ability and training than does present position. 6–1.

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Subscriptions, renewals, and membership fees for the current volume and orders for back numbers should be sent to the Executive Secretary, L. G. Monthey, 2702 Monroe Street, Madison 5, Wis. Back volumes, beginning with Volume 41, are available on microfilm. Write for details.

Articles concerned with instruction, demonstration, experimentation, or research in agronomy will be accepted for publication from members of the Society if deemed suitable by the Editorial Board. It is understood that articles submitted for publication have not appeared previously elsewhere and that they will not be offered for simultaneous publication in other journals without the consent of the Editor of the JOURNAL. At least one author of a paper must be an active member of the American Society of Agronomy.

Free publication in the JOURNAL is limited to four pages, with a charge of $25.00 per page for each additional page. The JOURNAL does not assume financial liability for halftone engravings or zinc etchings beyond $15.00 for each contribution. The author of any otherwise acceptable paper may have it published immediately by paying the entire cost of publication; publication of such a paper does not affect the prority of any paper on the regular schedule.

AGRONOMY JOURNAL

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Random Versus Systematic Arrangements in Non-Latin Square Field Experiments[1]

S. C. Salmon[2]

A RECENT review (2) of the literature on random and systematic arrangement of plots in field experiments led to the conclusion among others that the differences with respect to treatment and error variances are generally small, of doubtful statistical significance, and often of no practical importance. Comparisons, however, were limited to Latin Squares. Since the latter are seldom used in this country, a natural question is whether conclusions derived from them are applicable to the designs in common use. The study reported here was made to answer this question.

MATERIALS AND METHODS

Random and systematic arrangements were compared by superimposing hypothetical experiments on yield data from uniformity trials in much the same way as was done by Tedin (3) except that Tedin's study was limited to 5 by 5 Latin squares. The basic data were taken from 27 different sets of uniformity experiments with 14 different crops reported by 11 agricultural experiment stations in the United States and Canada. These comprised nearly all published uniformity data from the United States and Canada. A total of 113 separate and distinct hypothetical experiments comprising a total of 7,155 plot yields were set up. Since the same land was used for more than 1 year in some cases, the total number of individual plots of land was 5,238. In these hypothetical experiments the number of "treatments" ranged from 10 to 48 and the number of plots of each from 2 to 4. These numbers are typical of those used in varietal trials, fertilizer comparisons, and cultural tests in this country.

The size of plot varied from single rows of a rod or less in length to tenth-acre field plots. In a few cases very small original units were combined into larger units such as would be used in actual trials. The crop, the location, the size of plots, the year in which the crop was grown, the number of "treatments", the number of plots of each, and the author or authors are listed in table 1. The number of treatments to be compared and the number of plots of each (columns 3 and 4 of table 1) were determined somewhat arbitrarily. A very large number of different kinds of hypothetical experiments could be set up for any set of uniformity data. In the present study these were determined so that *(1)* all or practically all plots would be included, *(2)* the area used for each hypothetical experiment would be as nearly a square as appeared to be feasible, and *(3)* the number of treatments and number of replications would be within the limits of those commonly used in the United States.

For each hypothetical experiment the treatments were arranged at random and systematically. Tables of random numbers by Tippett (4) and by Cochran and Cox (1) were used for the random arrangements. Unlike the studies by Tedin, a separate set of random numbers was used for each replication of each experiment. Systematic arrangements were limited to those in which the replicated plots of each treatment were as uniformly and widely distributed over the experimental area as was possible. Such arrangements, like that illustrated in figure 1, are hereafter referred to as "good" systematic arrangements.

The possible number of "good" systematic arrangements in any experiment for which data derived by analysis of variance will give different estimates of error is equal to r(r—1), where r is the number of replications. The number of "good" systematic arrangements that are different, in the sense that the error variance for each treatment (as contrasted with the average for all treatments as given by analysis of variance) may be different, is much larger. These, however, are not the concern of this paper and are not considered. For those experiments in which more than one "good" systematic arrangement is possible, the particular one chosen to be included in table 1 was selected at random from all possible arrangements. In setting up both the random and systematic arrangements, no consideration was given to the character of the variation until after all calculations had been made.

EXPERIMENTAL RESULTS

For each "experiment", variances were calculated for "treatments" and for "error". These were expressed as a percentage of the within replication variance and are hereafter referred to as the expected variance. They are shown in table 1.

Variances and ranges for each "experiment", averages for each set of "experiments", and the grand average for all are shown in table 1. Frequency distributions of the variances are shown in table 2. The first items of interest in table 1 are the estimates of error which average 101.1% of the expected for the random arrangement and 110.1% for the systematic arrangment, a difference of 9.0 ± 2.1. This difference is highly significant which will, no doubt, be accepted by most people as showing that systematic arrangements do, in fact, lead to biased estimates of error.

For reasons stated in a recent paper (3) many agronomists, it is believed, will be more interested in a comparison of the treatment variances. The averages for these are 97.7 and 80.0%, respectively, for the random and systematic arrangements. This means that on the average about one-fourth more plots would be required in a random arrangement to assure as accurate a determination of mean yields as would be expected from "good" systematic arrangements on the fields from which these uniformity data were obtained. The range in mean yields of the individual treatments in each experiment averaged 1.5 cwt. per acre more for the random than for the systematic arrangements, as would be expected in the light of the difference in the treatment variances.

The differences between the treatment variances for random and systematic arrangements are much greater in some cases than in others. Especially interesting are the data for wheat in 1929 at the West Virginia Station. These comprise 9 separate hypothetical experiments and a total of 432 individual 10th-acre plots. The treatment variances averaged 61.5% of the expected as shown in table 1. There are 43 possible "good" systematic arrangements for these 9 experiments. The average of the 43 treatment variances (not shown in the table) is 63.2% of the expected. This means that if one had conducted a variety, fertilizer, or

[1] Received for publication Oct. 1, 1954.

[2] Principal Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A.

Table 1.—Treatment and error variances for randomly and systematically arranged plots in hypothetical field experiments.

Crop, location, size of plots, and author	Year	Number of		Random arrangement		Systematic arrangement		Range for mean yields	
		Treatments	Plots	Treatment	Error	Treatment	Error	Random	Systematic
		No.	No.	%	%	%	%	cwt. per A.	cwt. per A.
Corn, West Virginia, 14 by 61 ft., Garber, R. J. et el. (Jour. Amer. Soc. Agron. 23: 266–298. 1931)	1927	14	4	66.1	111.3	47.9	117.4	3.4	2.8
		14	4	68.5	110.5	66.1	111.3	3.9	7.5
		14	4	166.5	77.8	104.2	98.6	7.0	4.3
		15	4	162.5	79.2	58.2	113.9	8.1	6.6
		12	4	86.0	104.7	65.2	111.6	8.1	7.8
		12	4	123.2	92.3	84.9	105.0	9.4	8.1
		12	3	146.8	76.6	90.4	104.8	13.1	9.9
		10	3	57.3	121.3	37.9	131.0	7.1	6.2
				109.6	96.7	69.4	111.7	7.5	6.7
Ear corn, Montana, 23.5 by 317 ft., Harris, J. A. and C. S. Scofield (Jour. Agr. Res. 20:335–356. 1920)	1915	23	2	104.2	95.8	85.4	114.6	6.1	5.6
	1916	23	2	91.8	108.2	91.3	108.7	5.6	4.7
				98.0	102.0	88.4	111.7	5.9	5.2
Wheat, West Virginia, 14 by 61 ft., Garber, R. J. et el. (Jour. Agr. Res. 33:255–268. 1926)	1924	23	4	69.6	110.2	109.8	96.7	2.7	3.6
		22	4	117.4	94.2	63.8	112.1	5.1	3.6
		14	3	57.5	121.2	60.9	119.6	2.6	2.6
				81.5	108.5	78.2	109.5	3.5	3.3
Wheat, West Virginia, 14 by 61 ft., Garber, R. J. et el. (Jour. Amer. Soc. Agron. 23:266–298. 1931)	1929	15	4	90.7	103.1	31.6	122.8	3.3	1.7
		15	4	106.7	97.8	92.6	102.5	2.9	2.9
		15	4	77.5	107.5	50.9	109.6	5.1	3.6
		15	4	104.0	98.7	104.4	98.5	3.6	3.6
		15	2	148.7	51.3	57.7	142.3	5.7	3.3
		12	4	122.7	92.4	39.8	120.1	5.7	3.5
		12	4	163.0	79.0	55.8	114.7	5.9	3.8
		12	3	72.0	114.0	87.2	106.4	2.8	3.2
		10	3	48.9	125.5	33.3	133.3	3.0	2.2
				103.8	96.6	61.5	116.7	4.2	3.1
Wheat, Canada, 33 by 132 ft. and 33 by 120 ft., Wyatt, F. A. (Sci. Agr. 7:248–256. 1927)	1926	19	3	78.5	110.8	127.3	86.3	1.6	2.0
		19	3	105.6	97.2	56.8	121.6	3.0	2.0
				92.1	104.0	92.1	104.0	2.3	2.0
Oats, West Virginia, 14 by 61 ft., Garber, R. J. et el. (Jour. Amer. Soc. Agron. 23:266–298. 1931)	1928	15	4	125.0	91.7	69.3	110.2	2.8	2.1
		15	4	68.7	110.4	127.4	90.9	1.7	2.2
		15	4	47.0	117.7	81.0	106.3	1.6	2.0
		15	4	122.7	92.4	111.8	96.1	4.1	4.0
		15	2	101.3	98.7	42.1	157.9	5.3	3.7
		12	4	69.5	110.2	53.5	115.5	2.6	1.9
		12	4	128.8	90.4	57.5	114.2	4.2	2.9
		12	3	145.3	77.4	43.5	128.2	3.8	2.0
		10	3	83.7	108.1	133.3	83.3	3.1	4.6
				99.1	99.7	79.9	111.4	3.2	2.8
Oats, Nebraska, 5.5 by 264 ft., Kiesselbach, T. A. (Neb. Agr. Exp. Sta. Res. Bul. 13. 1918)	1916	23	3	121.1	89.4	133.2	83.4	3.7	4.6
		23	3	94.0	103.0	57.5	121.2	4.4	3.2
		23	3	134.6	82.7	103.9	98.1	3.5	3.7
				116.6	91.7	98.2	100.9	3.9	3.8
Oats, Montana, 23.5 by 317 ft., Harris, J. A. and C. S. Scofield (Jour Agr. Res. 20:335–356. 1920)	1917	23	2	90.4	109.6	138.3	61.7	4.7	6.1
Oats, Canada, 33 by 132 ft.; 33 by 120 ft., Wyatt, F. A. (Sci. Agr. 7:248–256. 1927)	1925	19	3	130.6	84.7	108.8	95.6	7.2	5.8
		19	3	68.3	115.8	53.1	123.4	5.6	4.3
				99.5	100.3	81.0	109.5	6.4	5.1
Barley, Montana, 23.5 by 317 ft., Harris, J. A. and C. S. Scofield (Jour. Agr. Res. 20:335–356. 1920. 36:15–40. 1927)	1919	23	2	95.4	104.6	43.1	156.9	8.2	5.6
	1921	23	2	97.1	102.9	66.7	133.3	5.6	5.3
				96.3	103.7	54.9	145.1	6.9	5.5

Table 1. (Continued).—Treatment and error variances for randomly and systematically arranged plots in hypothetical field experiments.

Crop, location, size of plots, and author	Year	Number of		Random arrangement		Systematic arrangement		Range for mean yields	
		Treat-ments	Plots	Treat-ment	Error	Treat-ment	Error	Ran-dom	System-atic
		No.	No.	%	%	%	%	cwt. per A.	cwt. per A.
Barley, California, 43.55 by 161 ft., Baker, G. S., et el. (Agron, Jour. 44:267–270. 1952)	1924	19	3	76.0	112.0	55.6	122.2	11.3	11.7
	1925	19	3	85.2	107.4	57.1	121.5	4.3	3.0
	1926	19	3	136.9	81.6	55.3	122.3	13.0	7.0
	1928	19	3	53.6	123.2	47.9	126.1	4.0	4.3
	1929	19	3	73.1	113.5	70.3	114.8	6.3	5.7
	1930	19	3	42.4	128.8	72.4	113.8	2.7	3.7
	1932	19	3	102.1	99.0	66.4	116.8	10.0	9.0
	1933	19	3	50.2	124.9	151.1	74.4	2.0	3.7
	1934	19	3	104.8	97.6	113.3	93.3	2.3	2.3
	1935	19	3	67.7	116.1	66.1	117.0	4.0	4.0
				79.2	110.4	75.6	112.2	6.0	5.4
Soybeans, West Virginia, 30 in. by 32 ft., Odland, T. E. and R. J. Garber (Jour. Amer. Soc. Agron. 20:93–108. 1928)	1926	30	3	97.4	101.3	87.1	106.4	0.7	0.7
		30	4	55.6	114.8	68.1	110.6	1.7	2.1
		25	3	86.6	106.7	51.0	124.5	0.6	0.3
		25	4	116.0	94.7	41.0	119.7	0.4	0.2
				88.9	104.4	61.8	115.3	0.9	0.8
Potatoes, Canada, 3 by 22 ft., Kalamkar, R. J. (Jour Agr. Sci. 22:373–385. 1932)	1925	48	3	115.2	92.4	47.7	126.1	72.6	48.4
		48	3	109.7	95.2	24.0	140.5	79.2	35.2
		48	3	113.2	93.5	114.6	92.7	33.0	39.0
		48	3	82.3	108.8	113.4	93.3	26.4	33.0
				105.1	97.5	74.9	113.2	52.8	38.9
Potatoes, New York, 34 in. by 72 ft.–7 in., Lyon, T. Lyttleton (Proc. Amer. Soc. Agron. 3:89–114. 1911)	1909	34	3	72.0	114.0	114.6	92.7	18.4	28.8
		34	3	52.0	124.0	89.4	100.5	11.3	18.4
				62.0	119.0	102.0	96.6	14.9	23.6
Sugar beets, Montana, 23. 5 ft. by 317 ft., Harris, J. A. and C. S. Scofield (Jour. Agr. Res. 20:335–356. 1920)	1911	23	2	66.0	134.0	80.5	119.5	69.0	84.0
Sugar beets, Minnesota, 22 in. by 33 ft., Immer, F. R. (Jour. Agr. Res. 44:649–668. 1932)	1930	30	3	63.3	118.3	73.9	113.1	67.2	62.4
		30	3	150.3	74.8	56.3	121.9	115.2	57.6
		30	4	132.8	89.1	71.9	109.4	100.8	72.0
		30	3	115.5	92.3	132.1	83.9	88.7	93.6
		30	3	110.1	95.0	75.2	112.4	98.4	72.0
		30	4	97.7	110.8	162.9	79.0	66.6	97.2
				111.6	95.1	95.4	103.3	89.5	75.8
Silage Corn, Montana, 23.5 ft. by 317 ft., Harris, J. A. and C. S. Scofield (Jour. Agr. Res. 20:335–356. 1920. 36:15–40. 1927)	1918	23	2	93.2	106.8	48.4	151.6	33.9	28.7
	1920	23	2	91.8	108.2	89.4	110.6	25.4	34.8
	1925	23	2	83.1	116.9	100.3	99.7	73.1	81.3
				89.4	110.6	79.4	120.6	44.1	48.3
Sorghum fodder (green weight) Texas, 40 in. by 82.5 ft., Stephens, J. C. and H. N. Vinall (Jour. Agr. Res. 37:629–646. 1928)	1915	32	4	78.8	107.1	67.4	110.9	15.0	14.3
		32	4	104.3	98.6	85.1	105.0	18.5	15.0
		32	4	95.5	101.5	73.9	108.7	15.5	13.0
				92.9	102.4	75.5	108.2	16.3	14.1
Soybean hay, West Virginia, 30 in. by 32 ft., Odland, T. E. and R. J. Garber (Jour. Amer. Soc. Agron. 20:93–108. 1928)	1925	42	3	82.3	108.8	70.3	114.8	9.3	7.8
		42	3	105.9	97.0	44.4	127.8	10.8	7.8
				94.1	102.9	57.4	121.3	10.1	7.8
Bromegrass, broadcast (green weight), Iowa, 3.5 ft. by 16 ft., Wassom, C. E. and R. R. Kalton (Iowa Agr. Exp. Sta. Res. Bul. 396. 1953)	1950	36	3	94.5	102.8	109.6	95.2	39.7	44.0
		36	3	98.9	100.5	60.7	119.7	69.5	52.6
		36	3	105.4	97.3	84.3	107.8	48.2	38.4
				99.6	100.2	84.9	107.6	52.5	45.0

Table 1. (Continued).—Treatment and error variances for randomly and systematically arranged plots in hypothetical field experiments.

Crop, location, size of plots, and author	Year	Number of		Random arrangement		Systematic arrangement		Range for mean yields	
		Treatments	Plots	Treatment	Error	Treatment	Error	Random	Systematic
		No.	No.	%	%	%	%	cwt. per A.	cwt. per A.
Bromegrass in rows (green weight), Iowa, 3.5 ft. by 16 ft., Wassom, C. E. and R. R. Kalton (loc. cit.)	1950	36	3	123.7	88.1	98.4	100.8	20.2	20.0
		36	3	79.0	110.5	81.5	109.3	15.0	16.3
		36	3	98.2	100.9	94.3	102.8	20.5	21.3
				100.3	99.8	91.4	104.3	18.6	19.2
Bromegrass and Alfalfa (green weight), Iowa, 3.5 ft. by 16 ft., Wassom, C. E. and R. R. Kalton (loc. cit.)	1951	36	3	100.1	99.9	88.8	105.6	25.4	30.9
		36	3	131.0	84.5	89.5	105.3	23.9	19.7
		36	3	101.0	99.5	90.1	105.0	29.0	26.7
				110.7	94.6	89.5	105.3	26.1	25.8
Oat hay, West Virginia, 14 by 61 ft., Garber, R. J. et el. (Jour. Agr. Res. 33:255–268. 1926)	1923	23	4	86.8	104.4	51.5	116.2	5.2	3.6
		22	4	84.9	105.1	52.9	115.7	8.5	8.5
		13	3	107.4	96.3	66.1	117.0	3.4	3.0
				93.0	101.9	56.8	116.3	5.7	5.0
Alfalfa, Montana, 23.5 ft. by 317 ft., Harris, J. A. and C. S. Scofield (Jour. Agr. Res. 20:335–356. 1920. 36:15–40. 1927)	1912	23	2	122.4	77.6	62.9	137.1	9.1	5.9
	1913	23	2	121.3	78.7	49.9	150.1	5.3	4.1
	1913	23	2	110.8	89.2	114.6	85.4	7.3	9.4
	1914	23	2	140.9	59.1	73.9	126.2	8.2	6.1
	1914	23	2	87.4	112.6	127.1	72.9	9.9	14.1
	1914	23	2	83.3	116.8	76.2	123.8	7.3	8.2
	1922	23	2	118.6	81.5	128.8	71.2	9.9	12.9
	1923	23	2	80.6	119.4	102.5	97.6	9.9	11.7
	1923	23	2	83.4	116.6	117.7	82.3	5.9	8.2
	1924	23	2	104.6	95.4	112.1	87.9	15.8	14.0
	1924	23	2	103.4	96.6	106.5	93.6	7.0	7.0
				105.2	94.9	97.5	102.6	8.7	9.2
Peanuts, Alabama, 3 by 16.7 ft., Bancroft, C. A. et el. (Ala. Agr. Exp. Sta. Progress Report Ser. 39. 1948)	1946	18	3	99.5	100.2	77.7	111.1	7.0	6.7
		18	3	62.9	118.6	72.3	113.8	5.8	6.7
		18	3	60.9	119.6	56.9	121.5	6.1	4.1
		18	3	59.1	120.4	66.9	116.6	5.5	6.8
				70.6	114.7	68.5	115.8	6.1	6.1
Peanuts, North Carolina, 3 by 12.5 ft., Robinson, H. F. et el. (No. Car. Agr. Exp. Sta. Tech. Bul. 86. 1948)	1939	36	3	127.4	86.3	67.4	116.3	8.0	6.7
		36	3	139.6	80.2	103.0	98.5	10.8	8.2
		36	3	99.8	100.1	81.0	109.5	5.4	5.6
		36	3	73.7	113.1	88.0	106.0	6.8	8.5
		36	3	115.4	94.9	81.0	106.4	7.5	8.7
				111.2	94.9	84.1	107.3	7.7	7.5
Peanuts, North Carolina, 3 by 12.5 ft., Robinson, H. F. et el. (loc. cit.)	1940	36	3	126.4	86.8	78.3	110.8	13.0	9.3
		36	3	99.5	100.2	106.6	96.7	9.3	8.0
		36	3	87.5	106.3	70.9	114.6	9.1	8.8
		36	3	122.6	88.7	66.5	116.8	8.7	6.1
		36	3	75.7	108.1	140.4	86.5	6.9	8.1
				102.3	98.0	92.5	105.1	9.4	8.1
Grand average				97.7	101.1	80.0	110.1	16.1	14.6

similar test with wheat on this particular field in 1929 with plots arranged at random, roughly one-third more plots would have been required to determine yields with the same degree of accuracy as would be expected from good systematic arrangements.

For corn on this same area 2 years previously the average treatment variance for the systematic arrangements shown in table 1 is 69.4% of the expected and the average for all possible "good" systematic arrangements (N=42) is 81.9% of the expected. Treatment variances for oats in 1928 also grown on this field are substantially the same as the over-all averages for all trials.

There are only a few cases in which the treatment variances equal or exceed the expected and for these the number of experiments and of plots involved is relatively small. In other words the tendency toward smaller treatment variances for systematically arranged experiments is not limited to particular crops or locations.

Table 2.—Frequency distribution of the variances shown in table 1.

Percentage of expected	Random		Systematic	
	Treatments	Error	Treatments	Error
10.1– 20.0	—	—	—	—
20.1– 30.0	—	—	1	—
30.1– 40.0	—	—	4	—
40.1– 50.0	3	—	10	—
50.1– 60.0	7	2	17	—
60.1– 70.0	11	—	16	1
70.1– 80.0	10	8	13	4
80.1– 90.0	14	13	17	8
90.1–100.0	17	28	6	16
100.1–110.0	16	28	11	22
110.1–120.0	9	25	7	35
120.1–130.0	12	8	4	17
130.1–140.0	6	1	4	4
140.1–150.0	4	—	1	2
150.1–160.0	1	—	1	4
160.1–170.0	3	—	1	—
	113	113	113	113

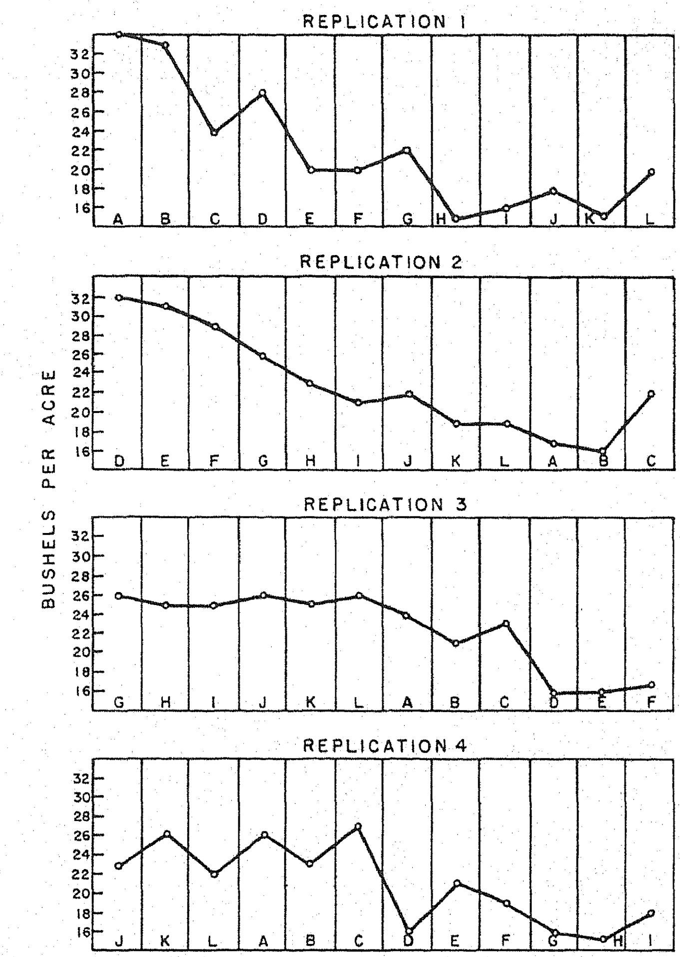

FIG. 1.—Yields of wheat and systematic arrangement of plots for a hypothetical experiment with wheat based on unifomity data from the West Virginia Agricultural Experiment Station in 1929. Letters A, B—L indicate individual treatments. The treatment variance for this particular arrangement was 39.8% of the expected value, and the average for all possible "good" systematic arrangements for this experiment was 35.5%. For wheat on this particular block of land in 1929 nearly 3 times as many plots would be required if randomly arranged to assure means as accurately determined as would be expected from "good" systematic arrangements.

Examination of the original yield data revealed that, for those experiments in which treatment variances were substantially less than the expected, there appeared to be a definite trend in productivity in one or more of the replicated series of plots. This is illustrated in figure 1 in which the yields of wheat in 1929 are charted for each individual plot of one of the hypothetical experiments based on uniformity data at the West Virginia Station. The letters indicate the systematic arrangement used in this particular case for the data in table 1. It will be noted that in each series of plots there is a definite downward trend in yield from left to right. With a "good" systematic arrangement such as here indicated, each treatment shares about equally in the low, medium, and high producing areas. Thus treatment B is represented by a plot in a high producing area in the first series, by another in a low producing area in the second series, and by two plots in medium productive areas in series 3 and 4. The same is substantially true for the other treatments. It follows that treatment variances are less and mean yields are more accurately determined than would be expected from random arrangements.

The potato data from Canada reported by Kalamkar afford an interesting example. The area from which the uniformity data were obtained was approximately 132 by 288 feet with rows of potatoes across the strip. Each row was harvested in 6 sections each 22 feet long. Hypothetical experiments were set up for each quarter of the experimental strip each comprising an area of about 66 by 144 feet. The average treatment variance for all possible "good" systematic arrangements for the two experiments at one end of the strip was 36.1% and for the other 109.3% of the expected. In the first case there was a definite trend in productivity from one end of each series to the other; in the latter there was not.

DISCUSSION

It appears from the data presented in this paper that the advantages of "good" systematic arrangements in relation to the accuracy of the means are somewhat greater than previously published data indicated, and that it would be even more difficult than previously supposed to justify the use of random arrangements for all field experiments. This would seem to apply especially to field plot experiments on land where a trend in yield from one end of a replication to the other is expected. Since the relative advantages and disadvantages of systematic and random arrangements have been discussed in another paper (2) it seems unnecessary to repeat them here.

Many agronomists will no doubt hesitate to use plot arrangements that do not assure a reliable estimate of error, and it is true of course that estimates of error may be seriously vitiated by any systematic arrangement. It is then a question of which is more important—dependable estimates of error or an accurate determination of means. In this connection, it seems significant that the distribution of errors from the systematic arrangement (table 2) is substantially the same as for the random arrangements but the errors are at a higher level. This being so, odds of something less

than 19 to 1 and 99 to 1 for systematic arrangements might be accepted as indicating statistical significance, or the calculated error variances might be reduced by say 10%, before significance tests are made. This latter seems justified by the fact that the extensive data published by Tedin as well as the data presented in this paper indicate that, on the average, error variances from "good" systematic arrangements may be expected to be higher than from random arrangements by about 10%. An easy and convenient way to achieve the same result would be to accept odds at the 8% and 2% levels respectively instead of at the conventional 5% and 1% levels as indicating statistically significant differences.

It should be recognized of course that the empirical data mentioned above are the only justification for this procedure. The fact that the data are extensive and that the distribution of error variances from "good" systematic arrangements is substantially normal suggests that such treatment would not lead to any serious misinterpretation of experimental data. Even so as previously suggested, random arrangements may be preferred for those situations where the need for a completely reliable estimate of error outweighs all other considerations.

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RE-EVALUATION OF EXTRA-CURRICULAR ACTIVITIES[1]

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A PSYCHOLOGICAL barrier lies astride the American college system of education. It has arisen from all the attitudes and the environment that allow extra-curricular activities to outweigh academic accomplishment in imporance and esteem. It is adversely affecting the ability of many students to determine what is significant in education and life careers.

American colleges and universities have taken great pride in the product of their educational systems. The characteristics most hoped for in this product were social adjustment and sense of responsibility, a well-rounded training including leadership training, and the "gift of gab." George F. Babbitt, the characterization of the American businessman by Sinclair Lewis, stands as a memorial. To realize this masterpiece, our institutions have emphasized the importance of extra-curricular activities—student government, clubs, fraternities, football fetish (as player or onlooker), dances, and bull sessions for the other fellow's point of view.

Regardless of the forces that erected it, the barrier now constitutes a self-sustaining philosophy, and students hew to it mightily. But like a rapidly rotating flywheel of ever increasing momentum, it has arrived at the speed of disintegration. Symptoms of its fragmentation can be seen in widely different sections of the United States. As reflected in the students' judgment of what is worthwhile, some of the symptoms are as follows:

(1) Small attendance at convocations featuring distinguished speakers.

(2) Lack of participation in religious groups by a majority of the most able students, alongside vigorous social activity. While "religious emphasis week" (of all denominations) is observed on many campuses, adoption of this practice also by some curriculum groups appears to be an attempt to place religion and profession in the same category on a competitive basis.

(3) Inadequate support for groups which at one time were the strongest student organizations. The success of the clubs depends on too few students whose accomplishments, both in the club and in the classroom, suffer accordingly.

(4) Readiness of a peripheral group to start a new club, publication, conference, or exposition, while a deserving activity already organized flounders for lack of support.

(5) Aberrations, such as "panty raids" would appear to be related to the general immaturity that prevails at times.

To some degree, at least, these symptoms are results of the emphasis on becoming well-rounded and socially adjusted—emphasis on extra-curricular activities.

Undergraduate Agronomy Clubs, which are urged to send delegates to the national meetings of the Society, are themselves testimonials of the esteem in which extra-curricular activities are held. Crop and livestock judging teams travel far and wide during the school year also. Such

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experience is, of course, most valuable even as professional training, but it must be weighed constantly against the time which it requires away from studies.

The high esteem for extra-curricular activities is not limited to college campuses. It is a well-recognized attitude today in business and professions. Many employers[3] regard participation in these activities, rather than academic zeal, as a criterion of a well-rounded personality and social adjustability. The success of the "bookworm" in business or the professions is not being discussed here, but it is clear that depreciation of academic accomplishment has already discouraged many college students from fully utilizing their time and resources for study. It has most certainly encouraged many indolent students to loiter through their golden opportunities, and it has unquestionably retarded their maturity.

American colleges have certainly turned out many "Babbitts" who are not very mature. Some Ralph Waldo Emersons have crossed the portals. Emerson, rather than Babbitt, was the champion of the individual freedom and self-reliance that we profess to admire. The psychological barrier erected by emphasis on the extra-curricular has obscured the objective of determining what to admire.

Pragmatism, or the reliance on "common sense" and trial and error, has become the sole guide in making decisions in most walks of life. This attitude is very tightly bound up with the attitude toward the extra-curricular. We attach relatively little importance to historical experiences and set out to solve our problems by trial and error. Quoting John Dewey (1) "Faith was once universally thought to be acceptance of a definite body of intellectual principles, acceptance being based upon authority—preferably that of revelation from on high. Faith in its newer sense signifies that experience itself is the sole ultimate authority." James A. Pike, Dean of Saint John's in New York City says "the best way to have belief in God is to start living as though He exists" (2). There is in all of this philosophy the implication that a start from practically anywhere can be made, and smooth sailing can be had forever afterwards by experimentation. This emphasis on learning-by-doing practically discards the valuable experiences and great accomplishments of the past. It eliminates the need for each individual's sharpening his mind and judgment by greater and more numerous experiences than can be had personally, in one life time. It erects a psychological barrier to "digging" for understanding.

Some consequences of this reliance on experience (extra-curricular activities, bull sessions) as the ultimate standard can be seen in public servants. Deep roots in the purged experiences of the past are not generally considered necessary. According to Joseph and Stewart Alsop, political commentators, "(Senator) Fulbright is interesting in another way. He is a senator who reads—an eccentricity he shares only with Douglas, Duff, and a few others"[4]. Where are our roots in the past, if not in the Senate? James Reston[5] compared the debates in Congress in the 1830's on the relations between Greece and Turkey with the 1947 debates on the then current Greek–Turkish relations. "The first are dignified and eloquent, the argument marching from principle through illustration to conclusion; the second (comprises) a dreary garble of debating points full of irrelevances."

In general, extra-curricular activities in college are motivated to too great an extent by the same pragmatism or experimentalism that is of so great importance in many walks of life outside college. Furthermore, the attitude that extra-curricular activity is more important, or even as important, as subject matter is basically wrong, and deprives students of the moral support and encouragement they need to get down and really "dig".

Attending a curricular club meeting might be revealing as to the inspiration and training that students are encouraged to think they especially need for careers after leaving college. It will certainly reveal considerable argumentation in which opinion is given greater importance than reason. This possibly could be regarded as valuable experience. However, such experience is comparable to that of a would-be farmer who gets started farming today with no knowledge of the proper use or even existence of fertilizers. The students carrying on the business of a club need to have an interest in and some knowledge of, the social, political, and economic experiences of groups of all sizes from families to nations to give them experience in working with groups. They need an understanding of the individual, and especially they need a perspective of the ideal. They will not get all they need as so many hope they can, and even believe they do, in a psychology class.

To say that subject matter is more important than extra-curricular activity is not to say that extra-curricular activity is not important. It can have great importance in its effect on the *esprit de corps* of the student body, giving the student a closer knit feeling of fellowship and a sense of belonging. But college is not the last chance anyone will have to develop a proper degree of extroversion. Certainly, curricular clubs do not need but one president or one vice-president at a time. Needless to say, they do not even need one president at a time unless there is a good number of responsible members in each. There is a vast amount of patience and understanding and will to serve involved in being a responsible member. Most of such "responsible" members are certainly qualified to be president. Such a state of affairs is almost certain to lead to an *esprit de corps* for the club and the institution. It should be excellent experience for the student. But we should not start out with these as the principal objectives and extoll the club or any extra-curricular activity above the work for which the college was founded. By so doing, we have built the barrier.

Maturity is universally recognized—by colleges and employers alike—as a primary requisite of a graduate, despite disagreement as to the means for nurturing it. At a conference at Virginia Polytechnic Institute in April 1954, W. C. Frederick, a production engineer for the General Motors Corp., said an ambitious young graduate needs to "stop for a minute and consider whether he has acquired mature judgment. Experience has shown it takes at least 5 years of various work assignments before a graduate has enough experience to be a successful supervisor or designer." Thus, it should be expected that the graduate will require some further training—even leadership training. It should be as easy to give to a graduate some training in leadership as in technical phases of industry or of agriculture.

[3] New York Times (news article on St. John's College Conference) p. 82LK, Oct. 25, 1953.

[4] New York Herald Tribune. "Fulbright's Fight with McCarthy" by Joseph and Stewart Alsop. 1954.

[5] New York Times. "The Decline of Eloquence in the Congress," editorial page, Jan. 31, 1954.

All undergraduate students need to get on with acquiring mature judgment, which is concerned not only with supervising and designing. At the same V.P.I. conference, Dr. George Perkins of the Reynolds Metals Company, (Louisville, Ky.) said that "the engineer must be more than a technical tool. His responsibilities to society demand that he interpret his work in terms of the society it will affect, and he must actively participate in the administration, control, and effective utilization of the fruits of his technical prowess." The patience which Mr. Frederick suggests and the philosophical analysis of technology's effect on society recommended by Dr. Perkins cannot be attained solely or even chiefly by ambitious participation in extra-curricular activities. Patience and understanding could perhaps best be acquired by studying philosophy or interrelationships, and by disciplining the mind with concentrated application. Plato has Socrates say (3) "Now when he is in this state of mind, (full of boundless aspirations and fancying himself able to manage the affairs of Hellenes and barbarians) if some one gently comes to him and tells him that he is a fool and must get understanding, which can only be got by slaving for it, do you think that, under such adverse circumstances, he will be easily induced to listen?" The getting of understanding only by slaving for it is, of course, the point that needs to be emphasized. Patience and understanding are integral parts of leadership.

Getting the proper perspective of extra-curricular activities is especially important at this particular time when, apparently, we are at a turning point of the pendulum swinging from collectivism toward individualism. Encouraging the development of a more profound outlook in the individual offers a great opportunity to, and indeed is, an imperative responsibility of our colleges and universities. Many signs point to the trend to individualism in the United States, if not in the rest of the world. In 1931, H. G. Wells (4) wrote "Personality, individuality, is a biological device which has served its end in evolution and will decline. A consciousness of something greater than ourselves—the immortal soul of the race is taking control of the direction of our lives."

Wells was an Englishman, but the sentiment he was expressing has had a strong influence even in America. What he said is the essence of an ideal collectivism. That such an ideal collectivism is impossible has many times been demonstrated. It should be obvious that what we can do for society depends first on what we can do with ourselves.

The individualism which motivated men like Carnegie and Vanderbilt and the capitalists of the British Industrial Revolution and others of that era, is now being appreciated for its true worth; and the developments of that era which so vastly improved the life of the common man are now being seen in a new light.

Yet, as the pendulum swings toward cultivation of the individual, we must strive to produce a type of individual nearer Jefferson and Emerson, than Babbitt. If we are to have a constructive and enlightened individualism rather than a predatory and vacillating one, we must place the greater emphasis on the matters of greater importance. We need a type whose roots grow deeply, taking the thinking of the past that stands up under careful study. This includes a development of a questioning alertness. A system of study to develop these characteristics should cover a great span of thinkers. More than aggressive leadership and participation in extra-curricular activities in colleges is required as training for leadership after college.

What is being done to remove this psychological barrier? The University of Chicago[6] embarked on a program for individual development in 1931. In 1942, this program was expanded. Aside from putting the greatest emphasis on scholastic achievement, Chicago instituted comprehensive examinations to replace course credit, and has adopted integrated courses of 1 year to 3 years in length. Also called for are selected readings and syllabi as course materials, teaching by the discussion method in small classes, and voluntary class attendance.

Modifications of programs at Harvard, Columbia, and Princeton Universities, and other institutions change the free elective system and sometimes practically eliminate it to insure more fundamental instruction.

In September 1953, Yale University issued a report calling attention to "student immaturity as evidenced by overemphasis on extra-curricular activities." A large community of students works in an environment where academic work is held less important than sports and college publications. A majority of the students puts second things first. Yale's newly stated objective according to last year's report is to fit men to render decisions on complicated problems and to state such decisions coherently and precisely. In seeking to accomplish this, a greater responsibility would be handed the student. Compulsory attendance at classes and other regulations in connection with lectures would be eliminated. It would be the student's own concern to get what he should receive from his college experience.

A start has been made towards getting academic pursuits and extra-curricular activities in the right perspective. It should be clearly evident that college cannot do all things for all people. Equal emphasis cannot be given all areas. Something must be singled out. Should it not be the most universally significant? Should it not serve as a starting point and stimulus to continuing growth? The "mind-block" to greater technical, sociological, economic, and political achievement by college students after graduation can be removed by putting first emphasis on the quest in college for great ideas and relationships.

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CAN TEACHERS BE EVALUATED?[1]

Darrel S. Metcalfe[2]

IT IS unnecessary to elaborate on the importance of high quality teaching. The fact is undeniable that the speed with which a society progresses and the effectiveness with which a country solves its social and economic problems are influenced to a great extent by the quality of its college teaching.

But something has happened in our educational system. Teaching today lacks prestige. In some groups the very word "teaching" suggests inferiority on the part of an individual. There seems to be some agreement with the inaccurate epigram, "He who can does, he who cannot teaches."

The Teaching Problem

Apparently there is some dissatisfaction among college teachers and a real concern about their profession. It is not uncommon to hear teachers express discontent, discouragement, or apathy; they believe that resident teaching does not get recognition on a par with research.

It is difficult to make a comparison between teaching and research on the basis of salaries paid, however, because of the differences in age, experience, tenure, and academic rank. There are those who insist that no valid comparison can be made; that research workers and teachers often are of different types, perform different functions, and that there is a different demand and supply situation so that they cannot be compared on the basis of salary scale.

A comparison of the relative salary, rank, and recognition given to resident teaching and to research personnel is not easy. Data obtained from a questionnaire sent to all Agronomy Department heads in our Land Grant Colleges and Universities indicate that there is a difference in top salaries paid to research men and to teachers but that the difference is not as great as is frequently believed (5). Other data indicate that the salaries of teachers and researchers are about equal up to the rank of associate professor. At the rank of associate professor and professor the salaries of research men are slightly higher than those of teachers. The men regarded as most valuable, and consequently the highest paid, are those good in both research and teaching (1).

The thought often is expressed that teachers do not advance as far in the academic world as research men because they do not continue "to grow." Perhaps this is true, and perhaps the teachers themselves are at fault. On the other hand, this might be true because they are not given the encouragement and recognition accorded those in research.

Perhaps it is but natural that, in the past, more emphasis has been placed on research than on teaching. The American desire to change things, speed up progress, and the American faith in the all-inclusive problem-solving benefits of science, leads to an intensity of efforts in research in Land Grant Colleges.

A considerable number of college staff members regard teaching as a necessary evil to the extent that it interferes with research and writing. The reason for this probably is their belief that good teaching is not likely to be recognized and rewarded to the same degree as good research.

When instructors are selected for college teaching, the emphasis is put too often upon research, and relatively small attention is given to the quality of teaching which the prospective candidates have demonstrated.

It has been said repeatedly that teaching cannot be evaluated as readily as research. Perhaps this is true, perhaps not. In the past several years many studies have been made and a considerable amount of opinion offered on the question of teacher evaluation.

Evaluation Difficult

The evaluation of a teacher's work is difficult in that there is not good agreement as to the results desired from instruction nor is there a reliable means of measuring these results. Before any attempt is made to evaluate, the objectives should be clarified. We need to have a clearer conception of the aims and the nature of higher education. It must be recognized, however, that any objectives listed can be only opinions; they would not have the approval of everyone.

Objectives in education vary from the general to the specific, from the professional to the personal, and from the ultimate to the immediate. Some insist that the chief objective in education should be to uphold national integrity. Others are concerned with ideals of culture and the better life and maintain that spiritual development and harmony are the true objectives; that the "whole" man should be developed rather than a specialized producer. To some, the objective should be to teach the students the answers to a thousand questions. But in contrast, some educators insist that the primary purpose of a college is to develop the thinking power of a student and that the student's mind should be treated more as a workshop than as a storehouse. In the process, the student becomes a different, more effective, more useful, and happier person than he might otherwise have been. This objective is achieved when the student develops his intrinsic ability to perform in a creditable manner the work he wants to do and to integrate through service his life to those of the other members of his community, state, and nation (3).

Education must help students to help themselves, each with his particular qualities and his family, and neighborhood background; and his own inherited and acquired philosophy, in whatever particular future may be his (4).

Garnet's statement "The best teacher is the one who kindles an inner fire, arouses moral enthusiasm, inspires the student with a vision of what he may become, and reveals the worth and permanency of moral and spiritual and cultural values," will be recognized by many as worthy of careful consideration.

Just as there appears to be no definite agreement upon objectives in education, to say nothing of reliable means of evaluating them, there appears to be the same problem in evaluating teachers.

Everyone has his own opinion as to who *is* and who *is not* a good teacher. Some 50 or more characteristics could be listed to evaluate a teacher. There are many such lists available, all interesting, none final. For example, 15 traits of teachers were considered highly important by at least a majority of the presidents of 419 liberal arts colleges; they

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are listed in the order of their relative importance as evaluated by these executives (6).

1. Inspires students to think for themselves and to express their own ideas.
2. Is emotionally stable and mature.
3. Organizes material and prepares carefully for each class meeting.
4. Is friendly, democratic, tolerant, and helpful in his relation with students.
5. Understands the problems most often met by college students.
6. His behavior reflects his ideals.
7. Takes broad rather than departmental views of educational problems.
8. Teaches students to take responsibility for planning and checking their own progress.
9. Shows active interest in continued professional study.
10. Has an infectious enthusiasm for teaching, that inspires students.
11. Has demonstrated skills in methods of instruction appropriate to his field.
12. Regards himself primarily as a college *teacher* rather than as a subject matter specialist.
13. Has successfully taught his subject in college.
14. Academic record in special field unusually high.
15. Has a congenial personality and a sense of humor.

In addition to his classroom record, a teacher should be evaluated also on his other contributions to an institution; his research ability, his ability to work with others, his extra-curricular activities, and his ability to promote good public relations.

Some assume that it is a comparatively simple matter to evaluate research workers—according to their contributions in the field of research, the quality of their writings, or merely by the total number of their papers per year. It is assumed, on the other hand, that there is no way to rate teachers.

But teachers *are* rated; there is no way to avoid rating them. When a new teacher is employed, when he is promoted, his salary increased, or he is assigned to important committees, he is rated. The question is not whether teachers *shall* be rated, but instead how the rating can best be done (2). Are there recognized systematic methods which can be used to evaluate teachers? The material written on methods of teacher evaluation is voluminous.

Evaluation Methods

Student opinions.—Teachers have been formally rated by college students for the last 25 or more years. Whether valuable or not, the idea of student rating is popular in collegiate thinking. Many teachers and students believe the formal teacher rating scale is the most reliable evaluation method. They believe the evaluation form to be the best barometer to register student reaction to methods and techniques used, activities provided, the degree to which course objectives were reached, and the personal qualifications of a teacher.

Although student opinions may be biased and unfair, usually they are not. Always these opinions are important. There are those who believe that a teacher rating scale has merit but that it must be used with extreme care; that a young student may not be able to differentiate between a good teacher and an entertaining lecturer. Some are convinced that a teacher rating scale can only measure a teacher's popularity, and that popularity is not a good measure of teaching ability and effectiveness. Others believe that the better students tend to rate a teacher higher than the poorer students.

Teacher rating forms may be formal and may ask the student to rate on the basis of 1 to 10 such items as: *(1)* Assignments; *(2)* Presentation of objectives of course; *(3)* Preparation for class meetings; *(4)* Ability to arouse interest; *(5)* Ability to interpret and clarify ideas; *(6)* Thinking required; *(7)* Quality of work required; *(8)* Examinations and grading; *(9)* Willingness to help; *(10)* Fluency and enunciation; *(11)* Tolerant and progressive attitude; and *(12)* Objectionable mannerisms.

It must be recognized that a formal rating scale cannot fully measure certain human relations which exist in the classroom.

Student opinions at the time a course is given are valuable. Students should be told they are not being asked to sit in judgment of their teachers but, instead, to give a fair and honest rating so that the teacher may improve his teaching.

Some teachers resent teacher rating scales; the majority of the better teachers like them. In some schools only the teacher being rated receives the results, which he uses for self improvement. In other schools, the ratings are evaluated, and the results given not only to the teacher but also to the department head, who in turn passes the results on to the dean.

Some schools use a course evaluation scale instead of a teacher rating scale. Here the teacher is not rated on such a personal basis. This often is preferred by the teacher who tends to be a sensitive individual.

There are other less formal methods of teacher rating. For example, a student may be given a sheet of paper at the end of a course and asked to comment on such questions as: Would you recommend this course to your best friend? What personal qualities of the teacher did you appreciate most? How do you rate the course relative to similar courses you have taken? How could the teacher improve this course? Voluntary evaluation also may be solicited about a course without guide questions.

Student reaction also may be obtained informally by interrogation or by conference with students at the close of the course. Student interrogation should be used with caution since students who are most willing to point out deficiencies in their teachers might be "sore heads" while the students whose opinions might be worth something might be more hesitant to criticize.

Graduating seniors might be brought into conference with teachers, counselors, and departmental heads to discuss the relative strength and weakness of the teaching program. This should be handled in such a way that students will be encouraged to interpret the facts objectively and not let it become a "gripe" session. Here, too, opinions may be biased.

Another way to get an evaluation at the student level is to have students file annual reports of student curriculum committees with the departmental curriculum committee. In this case the evaluation of teaching and teachers is handled through the departmental club. Evaluation should be kept as objective as possible. Sometimes the club will give a confidential teacher rating to the department head.

Alumni opinions.—Another way to evaluate teachers is from alumni reaction. The real test of an instructor's effectiveness is measured by the lasting quality of his instruction; the impressions, recollections, and habit of thinking that students retain years after graduation. It seems regrettable, however, that the teacher should have to await the evaluation of his teaching until his students have been

graduated for several years. Recognition salarywise and in other areas might come too late.

Comprehensive examinations.—Another method of evaluating teachers is to determine the achievement of students in a course, as measured by a comprehensive examination. To have a common test fair and reliable, the objectives of a course would need first to be clarified. The test would need to be such as would determine with some degree of certainty the extent to which the objectives had been reached.

Class visitations.—Some believe in the so-called "army" visitations to evaluate teachers. Class visitations may be embarrassing to the teacher, but not necessarily so if properly handled. Visitations must be made several times during the quarter or semester. One visitation might be under strained or unnatural conditions and might not reveal the true capabilities of a teacher. Visitations may be by the department head, by the dean, by a departmental committee, by a college committee, or by evaluation experts from outside the college.

Annual reports.—Teachers may be evaluated through formal annual reports. In these reports, the teacher is asked to list such items as his professional responsibilities, his committee assignments in the department, division, and college, his participation in state and national organizations, his television and radio programs, and his teaching plans for the coming year. The danger here is that one teacher may be too modest to list his accomplishments properly while another may pad his record. Such reports may be evaluated by his administrator, or by a non-interested group—a rank and pay committee—and advancements in rank and salary made accordingly. Also, teachers may be evaluated from wire or tape recordings made in the classroom. As in the former situation, an interested or a non-interested group listens to these records and rates the teacher. Another criteria for evaluation is for a committee of disinterested persons to look over not only the teacher's record but also the students' accomplishments. Still another approach is to have a "rank and pay committee," elected by the staff. This rank and pay committee, working with the dean or some other responsible administrative officer, is given the difficult task of setting up the criteria for determining which members of the staff are contributing most in terms of high quality teaching.

"Grape vine".—The "grape vine" system is another criterion for evaluating teachers. An administrator lends a "listening ear" to students, staff members, parents, alumni, and others. This can be too casual, may be gossipy, and certainly is not always reliable. Many administrators believe, however, that in this way they can rate their teachers adequately. It is questionable whether administrators can get a true and complete picture in this way. Some administrators believe that they can walk into a classroom and in less than 5 minutes evaluate a teacher; that teacher either has or has not the intangible "something."

CONCLUSIONS

Both administrators and teachers agree that evaluation is complex and that it cannot be accomplished satisfactorily by any one simple mechanical device. There are those who insist that teachers cannot be evaluated; that teacher evaluation is like the weather, to be talked about but that nothing can be done about it. But is it not safe to say that *unless* and *until* the teaching staff feels that quality teaching is recognized and rewarded, the full-teaching potential of an institution cannot be realized?

Good teaching must be evaluated in terms of its success in bringing about the desired results. There must be some agreement as to the desirable traits of good teachers. The formal methods sometimes used; course and instructor ratings by students and by alumni; impressions gathered from classroom visitations, from conversations with students and other teachers, and also from frequent talks with the teacher himself, all help to place the teacher in his rightful niche.

It would appear that for any method of evaluation to be satisfactory, it must be developed by the staff members themselves in cooperation with the head of the department and other administrators. In any evaluation procedure selected, all teachers should be as completely informed as is possible on both the bases and methods used, to what extent qualitative assessments are made, and the methods by which the judgment of the administrators at each level are supplemented or guided by other factors.

Certainly a department head should know of the success of the members of his staff as teachers, and he should be willing to put forth every effort to obtain recognition both in salary increase and in advancement in rank for good teaching. In recent years, more than ever before, much has been done to obtain satisfactory recognition for good teachers. However, there is still much to be done in this area. Any evaluation system adopted must serve only as a partial guide, and the personal judgment of the administrator still remains a most important factor.

Teachers should not feel sorry for themselves or develop defensive attitudes. Certainly there is no reason for such an attitude. Teaching is a profession to be proud of and appreciated. Teachers themselves need to develop a more positive attitude toward teaching; proud to say, "I'm a teacher." They must be encouraged to maintain their individual initiatives, to write, and to participate in both local and national affairs. It is important that they shall not "go to seed."

While personal satisfaction is a motivator, good teaching must be properly recognized and rewarded if it is to be given the attention which it deserves. Recognition of good teaching needs more than lip service.

One way to get good teaching is for administrators to let the teacher know he believes that good teaching is important. This can be accomplished through friendly and frank discussions of all facets of the teaching problem. Also, not only administrators but graduate faculty members generally should stimulate graduate students to prepare themselves to do good teaching.

Although there is no one simple and sure way to evaluate teachers, any method used helps focus the attention on good teachers and on good teaching.

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EFFECTIVE AGRONOMIC TEACHING—A SEMINAR[1]

P. H. Senn[2]

IT IS well known that many young agronomists, after receiving Ph.D. degrees, are retained by institutions of higher learning to instruct in agronomic courses. Many of them have had little training beyond that of conducting or assisting in laboratory sections or giving reports before seminar groups.

To assist new instructors in making adjustments in these new situations, some institutions have conducted orientation sessions for newly appointed staff members. In addition, others have held sessions for new and older instructors where topics on improving standards of instruction were presented by some of their outstanding teachers. Since this comes a little late, after a man is already on the job, it seems that such training might be pushed back into the student's graduate program where he could get some basic ideas and techniques on how to teach.

At the 1952 Meetings of the American Society of Agronomy held at Pennsylvania State University, Prof. H. L. Stier of the University of Maryland spoke of the use of local talent on many campuses to focus interest on better teaching. Following up this suggestion, a Graduate Agronomy Seminar (Crops) was started at the University of Florida, using as a general theme, "Effective Agronomic Teaching." Experienced teachers, young instructors, graduate students, and several members of the administrative staff from numerous university departments agreed to participate. The following subjects were included, together with the 1-hour periods allotted to each:

(a) Objectives—2 periods; *(b)* Methods—7 periods; *(c)* Evaluations—2 periods; *(d)* Counseling and Placement —1 period; *(e)* The teacher.

The two periods given to a discussion of general objectives pertaining to teaching included two topics, viz. foundations in education, and departmental and course objectives and course organization.

Foundations in education.—For a general presentation of the broad bases of education methods, a representative of the College of Education was called upon. He presented ideas for a general setting of the stage for the learning process, ways of learning, and creating a favorable environment for learning.

Departmental and course objectives and course organization.—For course objectives and organization, two speakers were invited from departments in the College of Agriculture—one from the Department of Entomology and one from the Department of Soils. Each gave broad departmental objectives, particularly those included in general or service courses designed for students from many departments. Also, major objectives and general organization for specific courses for graduate and undergraduate students were presented. Consideration was also given to the coordination of lecture material with laboratory exercises, greenhouse tests, plot demonstrations, and field trips, which often are parts of such courses.

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Methods.—More than half the number of seminar periods were spent in discussing methods or techniques commonly employed in teaching, and a rather wide area of subject matter was considered.

Finding, stimulating and holding student interest.—A staff member of the College of Education discussed the use of questionnaires, teacher-student planning, and the influence of the psychological climate as aids in finding student interests. In addition, class discussions, including the question method, speaking the student's language for clearer understanding, effective teachers' reactions to good questions, opportunities for doing field, greenhouse, and laboratory work, and the appeal to as many of the senses as possible, were advanced as ways of holding student interest.

Lecture, discussion, and textbook methods.—The relative values of the lecture, discussion, and textbook methods in teaching were presented by a staff member of the College of Education. Each method will have its own shortcoming, as well as its value for some groups, hence two or more of the methods are often desirable.

Student reports.—The value of such reports was discussed briefly under three headings by three men who were recognized as using them regularly and with a measure of success in their teaching programs.

Various types and kinds of oral and written reports were discussed by a member of the Agricultural Extension Service, who also devotes part time to teaching formal courses in Rural Leadership and Agricultural Extension Methods. Such reports are valuable segments in the training program of potential agricultural extension workers, and are useful in many types of classroom instructions.

Term papers are required by several departments in the College of Agriculture at Gainesville, Fla. A staff member of the Plant Pathology Department spoke on the nature and value of such papers, particularly to those students making an extended review of literature dealing with a specific topic.

Individual problems are offered in various subject matter areas and are usually intended for advanced students. Characteristics of a special problem paper that would show evidence of the student's having spent time and effort in collecting data and presenting written material that would merit college credit, were discussed by a qualified representative of the Department of Agricultural Engineering.

Laboratory work.—The laboratory method of teaching was discussed by a staff member from the Department of Botany and a graduate student from the Department of Soils. The staff member gave emphasis to the lecture areas that could be reinforced by laboratory exercises. He also emphasized the necessity for careful planning in advance for laboratory materials so as to be available when needed.

The student expressed ideas on what he hoped to get out of a laboratory period that would supplement and expand his knowledge beyond the lecture material. He spoke of his reactions to well planned laboratory exercises and also those which contributed little.

Field trips.—The part that field trips might play in an instructional program was discussed by a graduate student and a staff member from different areas. A staff member from the Department of Soils discussed the planning of a field trip in order to utilize time to the greatest advantage so as to enable the student to get the most benefit from the trip. The graduate student from the Department of

Vocational Agriculture gave his experiences of field trips which were a pleasure, and from which he felt he benefited greatly. He also mentioned some trips on which the instructor made it so laborious in taking excessive notes and rushing along all the while to cover much ground that the students could not keep up with the pace and missed the main lessons that no doubt were right before them.

Visual aids.—The sources of materials and types of equipment bearing on visual aids were handled under two headings—one dealing with sources of materials and other a demonstration of equipment.

Library services.—A representative of the university library department of visual aids told of the facilities available in that area, such as a library of films on many subjects, catalogued and cross-indexed and readily available to instructors on call. Mention was also made of the various types of projectors for slides, prints, and film strips, as well as still and motion pictures that were accessible. Machine operators, equipment delivery, and similar services were brought to the attention of the group.

Demonstrations of equipment.—The various types of projectors and screens, and the setting up of different pieces of equipment to give maximum efficiency were demonstrated by a member of the Agronomy staff. Careful planning in advance of the class period is often reflected in the effectiveness and smoothness of the demonstrated lecture.

Special aids.—The use of special aids in teaching was presented by young instructors from three Departments—Entomology, Plant Pathology, and Soils.

Blackboard outlines, sketches, charts, graphs, and models were exhibited and their uses demonstrated in teaching techniques. Color and color contrasts were shown as ways by which materials often difficult to understand may be more easily grasped.

Evaluations.—The task of evaluating a student's knowledge of a subject is one of the most difficult in the realm of teaching for most instructors. However, it is a general requirement that confronts all who teach. A representative of the College of Education discussed objectives of testing, length of tests, and various types of questions in common use. Also, the weighing of different types of questions for a grade evaluation was demonstrated.

A member of the University Board of Examiners explained the services available through his office. He discussed particularly progress tests and the assembly type of examination that are commonly machine graded and often administered to larger groups.

Counseling.—This appears to be receiving greater emphasis particularly in the larger institutions. The office of the Dean of the College of Agriculture was considered the appropriate area to contact for the broader view of counseling and guidance within the College. In addition to academic counseling, attention was called to the many other counseling services within the University available to students in need of help, such as the reading clinic, the speech and hearing clinics, the psychological clinic and in some schools, the marriage and family clinic—services that are provided to aid students to adjust themselves.

For counseling at the departmental level, a representative from the Department of Horticulture, recognized as doing a good job, spoke of the qualifications of a good counselor. Gaining the student's confidence, learning his background and interests, and sensing where the counselor might be helpful in the student's overall program were emphasized. Aiding in curriculum planning and keeping of simple yet systematic records on a student's progress were given as important facets of counseling service.

Many instructors will probably do some type of counseling either formally or informally, during their teaching careers; and to be effective, one should be well acquainted with as many facilities at his command as possible.

Placement.—Training and placement go together. A good student, well trained and well placed is a credit to an institution. The Provost for Agriculture, the administrative officer over the divisions of teaching, research, and extension at the University of Florida, was asked to speak of the opportunities in the various fields of Agriculture. Since his office serves as a medium of contact between outside agencies and the College of Agriculture, interview arrangements are planned through his office and the University Placement Bureau.

The teacher.—What does the administration look for in a good teacher and what does the student expect of a teacher, beyond that of knowing his subject? These qualities, of course, vary with individuals, but general thoughts on personal qualifications that might be looked for in the so-called ideal teacher, were presented by the Professor of Vocational Agriculture who is the teacher trainer for agricultural teachers on the high school level.

SUMMARY

Many graduate students of today will be, no doubt, in some kind of teaching positions very soon, be it a formal classroom course, agricultural extension, or participating in experiment station field days. An observing student planning to teach will have gathered much basic material through his association with good instructors. However, there are those who will have given little thought to teaching until they have accepted a position which carries teaching responsibilities.

It seems that a seminar on the general techniques of teaching might be made available to graduate students. Teachers from various areas are often glad to cooperate. In planning the seminar reported on herewith, not a single person approached declined an invitation to participate. All cooperated gladly. There is, no doubt, considerable talent on all campuses. Discovering and making use of this talent might be helpful not only to students soon to be teachers, but helpful to some instructors in doing a better job of teaching.

A Laboratory Method for Determining Digestible Nutrients[1]

R. L. Thurman and E. J. Wehunt[2]

GRAIN sorghum, sorgo, and corn silages differ in total digestible nutrients per unit of silage weight. The importance of this is shown by an association of dry matter content of the silages and total digestible nutrients. For example, Hegari silage averaged 38.1% dry matter with a total digestible nutrient content of 18.7%, as given by Morrison (4). Sweet sorghum silage averaged 25.3% dry matter and a T.D.N. content of 15.2%. Corn silage averaged 27.4% dry matter and a T.D.N. of 18.1%. Hilston and Gifford (1) found that the beef gains per ton of silage produced by a single variety varied from year to year. Knowledge of factors contributing to silage quality is of major importance in a program of breeding crops for silage uses.

A short laboratory method to determine the digestibility of plant materials for silage purposes would be most useful since it is very expensive to determine digestibility with conventional accepted methods where animals are employed.

PRELIMINARY WORK

Materials

Yield trials of corn and sorghum for silage were conducted at Fayetteville, Marianna, and Hope, Ark., during 1953 and 1954. However, due to drought, the plants failed to mature properly in 1954, except in the irrigated plots at Fayetteville and Marianna. The varieties were replicated four times in randomized blocks and fertilized adequately at all locations.

The stalks (leaves and heads attached) for the analyses were selected when the seeds were in the firm dough stage of maturity. The stalks from each plot were cut into two equal lengths. The upper portion of the stalks of one-half of the samples and the lower portion of the other one-half were combined as a plot sample. Grain, leaves and stalk samples were saved from some of the varieties. Plant materials of corn and two varieties of sorgo were also ensiled. The dried samples were ground through a 40-mesh screen. Samples collected in 1953 were ground and stored under refrigeration until the analyses were made in the fall of 1954.

Twenty-three corn and 50 sorgo silage samples were collected from silos throughout the state in December 1954 and January 1955.

Laboratory Method of Analysis

Section 37 of Loomis and Shull (2) was used as a guide in the processing of the ground samples. A 1-g. portion of the dried ground materials from each sample was treated with 100 ml. of a solution prepared with 1 ml. of concentrated HCl per 19 ml. of distilled water and autoclaved in open Erlenmeyer flasks at 15 lb. pressure for 1 hour. A drop of methyl red and enough 20% NaOH to nearly neutralize the acid present was added into the cooled flasks after autoclaving. The contents of each flask was filtered through a No. 42 filter paper, and the residue rinsed, dried, and weighed. The original sample weight minus the weight of the dried residue, converted to percentage, will be referred to as D.L.N. (digestible laboratory nutrients) in the results.

A laboratory analysis, as described above, was made on Atlas (semi-sweet), Tracy and Sart (sweet) sorgo varieties, Martin Milo and Early Hegari grain sorghums, and Dixie 22 and Funk 711 varieties of corn. The number of D.L.N. determinations for each variety varied from 2 to 15. The D.L.N. values reported are averages of all determinations made and have been adjusted to the average moisture percentage reported by Morrison (4) for similar materials.

Results

The average D.L.N. values of the 11 materials used are presented in table 1. The average D.L.N. for the sorgo silages used was 15.2 which is identical to the average T.D.N. of sorghum, sweet, silage reported by Morrison (4). It is not possible to make specific comparisons with the average values because the variance of the average value is not known and the comparison only indicates a relationship. The difference between the two values decreased with an increase in the number of samples analyzed for D.L.N. That is, samples varied greatly in D.L.N. and an average of the D.L.N. values of a few samples was always more variable than the average of a larger number of values. The greatest difference between the average D.L.N. of the materials used and the average T.D.N. reported by Morrison (4) was 2.5 for corn grain. The lower value for corn grain may have been due to the selectivity of the mill in the grinding. The D.L.N. values from several determinations from one sample were almost identical.

The 23 samples of corn silage contained only a very small amount of grain. The average percentage of dry matter of the corn and sorgo silage samples collected from

Table 1.—Average T.D.N. as reported by Morrison (4) and average D.L.N. of several silage materials.

Silage material	Averages		
	Reported by Morrison (4)		D.L.N.
	% dry matter	T.D.N.	
Sorghum, seed, sweet	89.2	77.5	78.6
Milo, grain	89.4	80.1	81.3
Hegari, grain	89.7	80.5	78.7
Corn, Dent, No. 2	85.0	80.1	77.6
Sorghum, sweet, silage	25.3	15.2	15.2
Corn, Dent, well matured, fair in ears, silage	26.0	17.1	16.2
Corn, fodder, medium in water, dry	82.6	53.9	51.5
Sorghum, fodder, sweet, dry	88.3	52.4	53.6
Sorghum, fodder, sweet, dry, high in water	65.7	39.7	39.7
Corn, fodder, dent, dough to glaze, green	26.9	19.1	16.8
Sorghum, fodder, sweet, green	24.9	17.3	16.0

[1] Research paper No. 1115 Journal Series, University of Arkansas, Fayetteville, Ark. Published with permission of the Director of the Arkansas Agr. Exp. Sta. Received Dec. 20, 1954.

[2] Assistant Agronomist and Graduate Student, respectively. The method was developed by the senior author and most of the preliminary checking of the method was a part of a thesis submitted to the University Graduate Council by the junior author in partial fulfillment of the Master's degree. The authors wish to express their appreciation to Joe W. Fleming, Assistant Professor of Horticulture, for his suggestions in the analyses.

throughout the state was very close to the averages reported by Morrison (4) for corn, dent, well matured, few ears and sweet sorghum, respectively. The corn silage samples averaged 16.4 and the sorgo 15.1 in D.L.N. which compares favorably with an average T.D.N. as reported by Morrison (4) of 16.3 and 15.2, respectively.

RABBIT FEEDING TRIAL

Materials and Methods

Two corn and eight 300-pound sorgo silage lots were collected from nine locations in the state and brought to Fayetteville for drying and processing. Samples 2 and 6 were corn silage. Sample 1, honey sorgo silage; 3, Tracy sorgo with several of the early heads removed; 4, Atlas sorgo with quick growth and harvested in the milk stage; 5, Atlas sorgo harvested 6 weeks after the firm dough stage of maturity and the birds had removed most of the seeds; 7, Sart sorgo which had matured only a few heads and had been frosted; 8, Tracy sorgo with below normal growth due to the drought; 9, Atlas sorgo with a production of 34 tons per acre; and 10, Tracy sorgo harvested 3 weeks after the firm dough stage of maturity and had also been stripped by a hail storm. Fifty pounds of each dried silage was mixed with 25 pounds of oats, 12.5 pounds of wheat, and 12.5 pounds of barley grain and ground. The lots were again mixed and pelleted.

Fifty New Zealand rabbits averaging 4½ weeks of age, separated into single pens, were used in the feeding trial. The pens contained metal floors which were sloped to the back and provisions for catching all of the manure. The pens were divided into 10 groups of 5 each. No group contained more than one rabbit from a litter. The silages were randomized among the 10 groups of pens.

The pelleted feeds were fed on a gradual basis for several days until the rabbits became accustomed to the feeds. At the end of the conditioning period, the pens were cleaned and feed weight records were started. The manure was collected daily and dried and all of it from a feeding period of 5 days was ground together before sampling. One-half pound samples of the pellets were collected at the start and at the end of each feeding period for dry weight determinations. At the end of the first 5-day feeding period, all rabbits received a uniform conditioning feed for 10 days. The silages were again randomized and after a chance for the rabbits to become accustomed to the pelleted feeds, another 5-day feeding period was completed.

The pelleted feed samples and the manure were chemically analyzed by a reputable commercial company and according to A. O. A. C. standards. The T.D.N. was determined according to the method outlined by Maynard (3). The D.L.N. of the pelleted feed samples was determined as described above.

Tab'e 2.—Percent dry matter, T.D.N. and D.L.N. of the 10 pelleted feed materials used in the rabbit feeding trial.

Feed Material	Percent dry matter	T.D.N.	D.L.N.
1	92.1	54.6	69.1
2	92.3	54.4	64.9
3	92.3	56.0	69.6
4	92.0	51.4	67.8
5	92.0	51.4	66.1
6	91.2	51.0	65.9
7	90.9	58.2	69.5
8	92.2	58.1	69.7
9	91.7	50.6	66.3
10	92.0	49.9	67.8

Results

The T.D.N. and D.L.N. values of the 10 pelleted silage-grain combination feeds are given in table 2. The T.D.N. varied from 49.9 to 58.2 and the D.L.N. from 64.9 to 69.7 among the 10 feeds. However, the lower T.D.N. values were expected because Voris, *et al.* (5) reported that rabbits digest somewhat less fiber and N.F.E. than do such large animals as cattle. A correlation of + 0.656, which was significant beyond the 5% level, was found between the T.D.N. and T.L.N. values of the 10 feeds.

SUMMARY AND CONCLUSIONS

A laboratory method for determining digestible nutrients in silage materials is presented. The method, designated as D.L.N., appears to give results which are associated with the digestibility of silage materials as determined by animal feeding trials.

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The Effects of Variations in Plant Density, Soil Moisture, and Fertility Levels Upon Rubber Production by Krim-Saghyz[1]

Albert S. Hunter and Lauren M. Burtch[2, 3]

KRIM-SAGHYZ, *Taraxacum megalorrhizon,* is a rubber-bearing dandelion native to the Crimean area of Russia. Seeds of krim-saghyz and of kok-saghyz *(T. kok-saghyz)* were supplied to the United States Department of Agriculture by Russia shortly after the entrance of the United States into World War II. During the war years, major attention was given to study of the rubber-production capabilities of kok-saghyz, which has reportedly been grown extensively in Russia. A report on the war-time studies on rubber production from kok-saghyz in the United States has been made by Whaley and Bowen.[4] Little attention was given to krim-saghyz. It is understood that the Russians have not cultivated it to any great extent, because it is climatically adapted to a relatively small area, in contrast with the much wider climatic adaptation of kok-saghyz. A small planting of krim-saghyz made during the war by George Harrison at the U. S. Cotton Field Station, Shafter, Calif., gave results indicating its possible superiority over kok-saghyz as a rubber producer under San Joaquin Valley conditions. The war-time rubber research program was curtailed before the possibilities of krim-saghyz could be fully evaluated. Upon reactivation in 1948 of the agronomic research program on domestic rubber-producing plants, it appeared desirable to study further the potentialities of krim-saghyz as a source of rubber. The plant is highly apomictic and uniform, and it is to be expected that improvement through breeding will be relatively slow in comparison with that of the highly sexual and variable kok-saghyz. Accordingly, an experiment was established to test the effects of variations in plant density, soil moisture, and soil fertility upon rubber production by krim-saghyz.

As a supplement to the main experiment, a planting of kok-saghyz, krim-saghyz, and tau-saghyz *(Scorzonera tau-saghyz,* closely related to the garden salsify and also native to Russia) was made for the purpose of comparing the rubber-production capabilities of these three plants. The kok-saghyz seed was from some of the selections made during the war from the Russian imports.

EXPERIMENTAL PROCEDURES

In the main experiment, 3 soil moisture treatments, 4 fertilizer treatments, and 3 stand levels were factorially combined in a split-split plot design, with 4 complete replications. The experimental area was bedded on 28-inch centers; 2 rows, 12 inches apart, were seeded on each bed. The moisture plots were 12 rows wide and 80 feet long; stand plots, 4 rows wide and 80 feet long, were randomized within moisture plots; and fertilizer plots, 4 rows wide and 20 feet long, were in turn randomized within stand plots. Buffer strips 4 rows (2 beds) wide separated pairs of moisture plots within blocks.

The experiment was established on Greenfield coarse sandy loam soil at Salinas, Calif., on Nov. 22, 1948, by planting seed at 3 rates to give stands averaging (S_1, thin stand) 9.1, (S_2, medium stand) 19.5, and (S_3, dense stand) 34 plants per linear foot of row. Fertilizer variables were established as follows: F_1, natural fertility level of the soil (no fertilizer); F_2, fertility level produced by application of 50 pounds N per acre at planting and 100 pounds N in April 1949 (N); F_3, fertility level produced by application of 100 pounds P_2O_5 per acre at seeding (P); and F_4, fertility level resulting from application of 50 pounds N, 100 pounds P_2O_5, and 75 pounds K_2O per acre at seeding and 100 pounds N in April 1949 (NPK). Fertilizers were applied as bands between rows; sources used were ammonium sulfate, superphosphate, and potassium sulfate. Beginning April 20, 1949, after winter rains, and continuing through October 1949, 3 variations in soil moisture were produced by irrigating when the soil moisture tension at the 6-inch depth in the S_3F_1 plots reached the following values: M_1 (dry), approximately 15 atmospheres, as indicated by Bouyoucos block resistances of 100,000 ohms or more; M_2 (medium), approximately 3.5 atmospheres, as indicated by Bouyoucos block resistances of approximately 5,000 ohms; and M_3 (wet), 0.85 atmosphere, as measured by soil moisture tensiometers.

In accordance with these criteria for the need of irrigation, the M_1, M_2, and M_3 plots were irrigated 5, 7, and 11 times, respectively, between April 20 and Oct. 28, 1949. Soil moisture tension observations were omitted in 1950; between April 20 and the July harvest, the M_3 plots were irrigated three times, the M_1 and M_2 plots once each.

All plots of the experiment were sampled in July 1949 and July 1950. The plots of fertility treatments F_1 (no fertilizer) and F_4 (NPK), stand levels S_1 (thin) and S_3 (dense), and moisture treatment M_3 (wet) were sampled in October 1949 and February and May 1950. At each date all roots to a depth of 18 inches were dug by hand from 5 feet of row at a random location within each plot. The plant tops were removed at the crown, the plants were counted, and the samples were dried at 65° C., weighed, ground, and analyzed for rubber. Analyses of variance were made.

The kok-, krim-, and tau-saghyz of the supplementary experiment were seeded in randomized blocks, with five replications, in November 1948, adjoining the main experiment. Kok- and krim-saghyz seeds were planted at the rate of approximately 100 seeds per foot of row; the quantity of tau-saghyz seed available permitted the planting of only 15 seeds per foot. The kok- and krim-saghyz plots were sampled 7½ months after seeding and plots of all 3 plants were sampled at 11½ and 20 months. Samplings were made as in the main experiment. Counts were made of the surviving plants per foot of row, and yield of roots, rubber content, and yield of rubber were determined.

Approximately 11 months after seeding, roots of kok- and krim-saghyz in the supplemental experiment were harvested by 3-inch depth increments to 12 inches, in order to obtain information on the quantity of rubber that could be procured by harvesting these plants to different depths.

RESULTS AND DISCUSSION

The plants seeded in November 1948 had emerged by early December and grew vigorously during the winter and early spring months of 1949. It was characteristic of the krim-saghyz plants in this experiment that evidences of dormancy began to appear in May each year, regardless of irrigation or other treatment. The leaves first become chlorotic in appearance and subsequently died back to the root crown. During most of June and July the plants were dor-

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[3] The authors are gratefully indebted to Marion C. Slattery, who analyzed the plants for rubber, and to Eleanor C. Taylor, who made statistical analyses of the data.

[4] Whaley, G. W., and Bowen, J. S. Russian dandelion (kok-saghyz), an emergency source of natural rubber. U.S.D.A. Misc. Pub. 618. 1947.

mant, with very little, if any, growth occurring. In late July or early August the dormancy was broken, new leaves appeared, and growth was resumed, continuing through the fall, winter, and early spring.

Data from the first harvest, made in July 1949, approximately 7½ months after seeding, are presented in table 1. The plants were dormant. In digging the roots to a depth of 18 inches, it was observed that, in general, the root systems of the plants of the densest stand (S_3) were contained in the 12- to 15-inch depth of soil, while roots of plants of the least dense stand (S_1) were often 1/16-inch or more in diameter at the 18-inch depth. Some of the larger roots had crown diameters of the order of ⅜-inch.

Each of the three variables, moisture, stand, and fertilizer treatments, had highly significant effects upon root yield at the first harvest. The highest yield, 5,988 pounds per acre, was produced by the combination of medium moisture, dense stand, and NPK fertilizer ($M_2S_3F_4$); the lowest yield, 2,441 pounds per acre, was associated with medium irrigation, thin stand, and no fertilizer ($M_2S_1F_1$). The medium (M_2) and high (M_3) moisture treatments gave significantly higher yields than the low (M_1) treatment. Root yield increased significantly with stand density, mean yields of 2,955, 3,617, and 4,169 pounds per acre being produced by stand levels S_1, S_2, and S_3, respectively. There was a significant interaction of stand level and moisture treatment; yields for stands S_2 and S_3 increased with increased moisture, or decreased tension, while at stand level S_1 (thin) variations in moisture had no significant effects. The yield was significantly increased by both N and NPK fertilizers, but not by P alone. The mean yield for all treatment combinations was 3,580 pounds per acre.

The rubber content of the roots at the first harvest was not significantly affected by moisture, stand, or fertility, but there was a significant interaction of stand and fertility treatments; greater increases in rubber were associated with N and NPK fertilizers in combination with the thin (S_1) than with the dense (S_3) stand. The average rubber content was 1.90%.

Effects of soil moisture treatment upon rubber yield were not statistically significant. Both stand level and fertility treatment produced significant effects, and there was a significant interaction between these two variables. The highest rubber yield was produced by the densest stand of plants. Significant increases in rubber yield were produced by N and NPK fertilizer treatment, and these two treatments were much more effective in combination with the dense than with the thin and medium stands. The maximum yield, 140 pounds per acre, was produced by the combination of high moisture, dense stand, and N fertilizer ($M_3S_3F_2$).

The final harvest in this experiment was made July 18, 1950, approximately 20 months after seeding. Plants were again dormant. Moisture treatment differences were not as great in 1950 as in 1949. No fertilizer was applied in 1950. The data for the final harvest, summarized in table 2, reflect the effects of stand level variation throughout the life of the plants, of the wide differences in 1949 and slight differences in 1950 moisture treatment, and of the initial fertilizer applications.

The greatest yield of roots obtained from any treatment combination, (5,570 pounds per acre), the maximum rubber content (5.48%), and the maximum yield of rubber (305 pounds per acre) were produced by the plants grown with medium moisture, dense stand, and 150 pounds N per acre ($M_2S_3F_2$). Moisture treatment effects were not significant. The greatest mean yield of roots and rubber were produced by the plant stand of greatest density (S_3) and by the NPK (F_4) fertilizer treatment. The mean concentration of rubber was significantly increased by both P (F_2) and NPK (F_4) fertilizer. There were no significant inter-

Table 1.—Summary of data from Krim-saghyz harvested July 6–8, 1949. Means of 4 replications.

Fert. treat.	Moist. treat. M_1 Stand level				Moist. treat. M_2 Stand level				Moist. treat. M_3 Stand level				Means for moist. treats. Stand level			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
								Yield of Roots, Lbs./A.								
F_1	2541	2770	3006	2772	2441	2665	3139	2748	2559	3431	3553	3181	2513	2955	3233	2900
F_2	3439	3437	4050	3642	3487	3916	5312	4238	2726	4764	5606	4365	3217	4039	4989	4081
F_3	2702	2728	2481	2637	2676	2883	3439	2999	2072	3933	3754	3253	2483	3181	3224	2963
F_4	3519	3551	3947	3672	3486	4144	5988	4539	3823	5192	5759	4924	3609	4295	5231	4378
Mean	3050	3121	3371	3180	3022	3402	4469	3631	2795	4330	4668	3931	2955	3617	4169	3580
								Per Cent Rubber								
F_1	1.68	1.94	1.71	1.77	1.69	2.31	1.81	1.93	1.75	1.96	2.08	1.93	1.70	2.07	1.86	1.87
F_2	1.72	1.64	2.00	1.78	1.79	1.99	2.19	1.99	1.54	2.07	2.32	1.97	1.68	1.90	2.17	1.91
F_3	1.72	1.60	1.57	1.63	2.12	2.32	1.71	2.05	1.97	1.86	1.66	1.83	1.93	1.92	1.64	1.83
F_4	1.70	2.04	2.00	1.91	1.78	1.90	2.16	1.94	2.12	2.01	2.35	2.16	1.86	1.98	2.17	2.00
Mean	1.70	1.77	1.82	1.77	1.84	2.13	1.96	1.97	1.84	1.97	2.10	1.97	1.79	1.96	1.96	1.90
								Yield of Rubber, Lbs./A.								
F_1	43	53	54	50	41	67	59	55	46	71	89	68	43	64	67	58
F_2	60	56	84	66	62	79	117	86	41	102	140	94	54	79	114	82
F_3	49	42	39	43	60	79	59	66	41	80	62	61	50	67	53	57
F_4	62	73	82	72	63	82	129	91	84	111	138	111	70	89	116	92
Mean	53	56	65	58	56	77	91	75	53	91	107	84	54	75	87	72

Least significant difference (P = 0.05) between:	Yield of roots	Percent rubber	Yield of rubber
Moisture treatment means	345	N.S.	N.S.
Stand level means	457	N.S.	13
Fertilizer treatment means	368	N.S.	12
Moisture × stand means	796	N.S.	N.S.
Stand × fertilizer means	N.S.	0.29	22

Table 2.—Summary of data from Krim-saghyz harvested July 18, 1950. Means of 4 replications.

Fert. treat.	Moist. treat. M_1 Stand level				Moist. treat. M_2 Stand level				Moist. treat. M_3 Stand level				Means for moist. treats. Stand level			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
	Yield of Roots, Lbs./A.															
F_1	2556	2836	3461	2951	3403	2987	3737	3375	2951	3694	3924	3523	2970	3172	3707	3283
F_2	3792	4464	3959	4071	3181	5105	5570	4618	3600	4631	4181	4137	3524	4733	4570	4275
F_3	3156	2370	3362	2963	3633	3688	2921	3714	3504	3737	3376	3539	3431	3265	3219	3305
F_4	4030	4263	4346	4213	4842	5655	4787	5094	4033	4748	5562	4781	4301	4888	4898	4696
Mean	3383	3483	3782	3549	3764	4358	4253	4125	3522	4202	4260	3995	3556	4014	4098	3889
	Per Cent Rubber															
F_1	3.58	3.84	4.33	3.91	3.63	4.14	4.67	4.14	4.29	4.35	4.14	4.26	3.83	4.11	4.38	4.10
F_2	4.07	3.94	4.09	4.03	4.09	4.24	5.48	4.60	4.37	4.53	4.90	4.60	4.17	4.23	4.82	4.40
F_3	3.82	4.48	4.30	4.20	5.06	5.08	4.71	4.95	4.20	4.77	4.72	4.56	4.36	4.77	4.57	4.56
F_4	4.48	4.10	4.46	4.34	4.58	4.57	4.96	4.70	4.07	4.71	5.21	4.66	4.37	4.46	4.87	4.56
Mean	3.98	4.09	4.29	4.12	4.34	4.50	4.95	4.59	4.23	4.59	4.74	4.52	4.18	4.39	4.66	4.40
	Yield of Rubber, Lbs./A.															
F_1	92	109	150	117	123	124	175	140	126	160	163	149	114	131	163	136
F_2	175	176	162	171	130	216	305	217	158	210	205	191	154	201	224	193
F_3	120	106	144	123	184	187	138	169	147	178	159	161	150	157	147	151
F_4	181	175	194	183	222	259	237	239	164	224	290	226	189	219	240	216
Mean	142	141	162	148	165	196	214	192	149	193	204	182	152	177	193	174

Least significant difference ($P = 0.05$) between:	Yield of roots	Percent rubber	Yield of rubber
Moisture treatment means	N.S.	N.S.	N.S.
Stand level means	306	N.S.	22
Fertilizer treatment means	447	0.37	24

actions. As an average for all plots, at 20 months after seeding the yield of roots was 3,389 pounds per acre, the rubber content was 4.40%, and the yield of rubber was 174 pounds per acre. Between July 1949 and July 1950 the mean yield of roots increased only 309 pounds per acre, while rubber content and yield of rubber more than doubled, increasing from 1.90 to 4.40% and from 72 to 174 pounds per acre, respectively.

In order to determine the course of accumulation of roots and rubber and the concentration of rubber with time, the plots of stand levels S_1 and S_3, fertilizer treatments F_1 and F_4, and moisture treatment M_3 were sampled at three dates intermediate between the first and final harvests. The means of the data from these harvests are presented graphically in figure 1, together with data from the first and the final harvest of the same plots. Data from the four treatment combinations are averaged for each harvest date, since essentially similar trends with time were found in the case of the four treatments. Each datum point represents the mean for 16 plots.

There was a decrease of 1,268 pounds of roots and 12 pounds of rubber per acre and an increase of 0.40% rubber content between July and October. At the October sampling the plants had resumed growth after summer dormancy; it was very noticeable that the roots were shriveled and shrunken in appearance, in contrast to the smooth, firm appearance at the July harvest. It is probable that the new growth of the plant tops was made at the expense of carbohydrate materials in the roots; this would explain the decrease in total root weight and accompanying increase in rubber concentration.

At the February and May samplings the plants were actively growing. It is apparent from figure 1 that between October and February and between February and May the

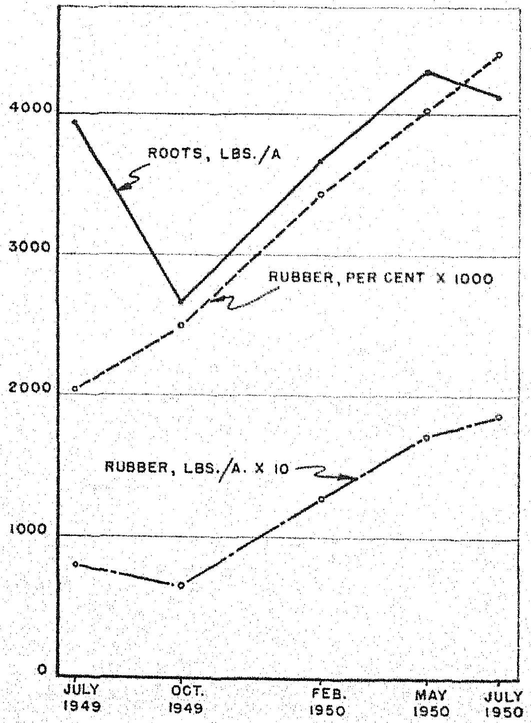

FIG. 1.—Changes in root and rubber yield and concentration of rubber in krim-saghyz plants with time.

yield of roots continued to increase, as did the concentration and yield of rubber. At the February sampling the yield of roots had not yet reached the level of the previous July; by the May sampling date the yield of roots had surpassed that of July. The data from the July 1950 harvest

indicate that the roots had lost weight since May. From these data it would appear that the greatest weight of krim-saghyz roots was present at the end of vigorous growth and the onset of dormancy in May. The concentration of rubber in the plants increased continuously with time, as did the yield of rubber after October.

The results of the supplemental experiment to compare kok-, krim- and tau-saghyz are set forth in table 3. At the June sampling the plant densities of the kok- and krim-saghyz were essentially the same. The number of kok-saghyz plants declined with time to a density about one-half that of the krim-saghyz. The stand of tau-saghyz was relatively sparse. At all dates, the weight of krim-saghyz greatly exceeded that of kok-saghyz roots, which in turn was greater than that of tau-saghyz. At the first two sampling dates, the rubber content of kok-saghyz was higher than that of krim-saghyz; at the third harvest, rubber concentration in the three plants was similar. The rubber yield of krim-saghyz was much higher than that of kok-saghyz at the first and third samplings; the two were similar at the second sampling; and both were superior to tau-saghyz. The tau-saghyz might have compared more favorably with the other two plants had it been seeded at greater density.

In November 1949 the roots of the kok- and krim-saghyz were harvested by 3-inch depth increments to 12 inches. The plant tops were also harvested. Weight and rubber content of each 3-inch increment of roots and of the tops was determined. Total weight of kok- and krim-saghyz roots harvested (12 inches) were 1,919 and 1,662 pounds per acre, respectively. Of these amounts, 55% of the kok- and 41% of the krim-saghyz were dug from the top 3 inches; 74 and 70% were harvested from the top 6 inches; and 85 and 84% were obtained from the top 9 inches. The concentration of rubber in roots of both plants increased with depth, ranging from 2.8% in the upper 3 inches to 4.3% in the lower 3 inches of depth of kok-saghyz and from 1.4% to 2.7% for the same depths of krim-saghyz. In the case of kok-saghyz, 36, 72, and 79% of the total rubber in the 12 inches of roots was found in the upper 3, 6, and 9 inches, respectively; for krim-saghyz, these values were 22, 63, and 75%. The tops of the kok- and krim-saghyz plants, respectively, weighed 807 and 1,493 pounds per acre and contained 5 and 15 pounds of rubber; the rubber concentrations were 0.7 and 1.0%.

The data from these two experiments indicate that under Salinas Valley conditions rubber yields of 140 pounds per acre in 7½ months, and 305 pounds per acre in 20 months from seeding may be obtained from krim-saghyz. Kelley, *et al.*[5] reported rubber yields of 823 to 1,336 pounds per acre from guayule harvested at 19 to 21 months after seeding. The maximum yield of 140 pounds of rubber per acre, obtained from krim-saghyz in 7½ months, compares more favorably with the 170 to 280 pounds produced by guayule in 10 months.[5] The small size of the individual roots and the considerable depth to which they must be harvested are disadvantages of the saghyzes.

[5] Kelley, O. J., Haise, H. R., Markham, L. C., and Hunter, A. S. Increased rubber production from thickly seeded guayule. Jour. Amer. Soc. Agron. 38:589–613. 1946.

Table 3.—Summary of data from supplementary experiment comparing Kok-, Krim-, and Tau-saghyz. Means of 5 replications.

Date	Kok-saghyz	Krim-saghyz	Tau-saghyz
	No. Plants/Ft. of Row		
June 1949	28	33	*
October 1949	25	35	3
July 1950	15	32	2
	Yield of Roots, Lbs./A.		
June 1949	531	2210	*
October 1949	942	1632	363
July 1950	896	2403	414
	Percent Rubber		
June 1949	3.0	1.9	*
October 1949	4.7	2.3	5.5
July 1950	6.1	5.5	6.7
	Yield of Rubber, Lbs./A.		
June 1949	16	41	*
October 1949	44	39	20
July 1950	54	123	31

* Tau-saghyz not harvested on this date.

SUMMARY

The rubber production potentialities of krim-saghyz, an apomictic Russian dandelion, were explored in an experiment involving three densities of plant stand, three irrigation treatments, and four fertilizer treatments in factorial combination. Plants were seeded in the Salinas Valley of California in November 1948. All plots were sampled after approximately 7½ and 20 months. The course of rubber accumulation with time was followed by periodic sampling of selected plots. In a supplemental experiment, rubber production by krim-, kok-, and tau-saghyz was compared.

Maximum rubber yields of 140 pounds per acre were produced by krim-saghyz, harvested to a depth of 18 inches, in 7½ months from seeding; at 20 months, 305 pounds of rubber per acre were harvested from plots of the best treatment combination. At each harvest, yields of roots and rubber were highest from plots with greatest density of plant stand and those to which N or NPK fertilizer was applied. Soil moisture had significant effects on root yield, and on rubber yield at one harvest only, but was without significant effect on rubber concentration in the plants. Concentration and yield of rubber increased continuously with time, but the weight of roots decreased during periods of dormancy.

The rubber production obtained from krim-saghyz was less than half that reported for guayule at approximately the same age at harvest. Krim-saghyz produced considerably higher rubber yield than kok-saghyz or tau-saghyz.

Relative Yields of Varieties of Wheat on Fallow and on Cropland at Hays, Kans., 1921-52[1]

John D. Miller and W. M. Ross[2, 3]

IT IS generally recognized that variety yield tests should be conducted in a manner to distinguish real differences among varieties. The tests also should be conducted under soil and climatic conditions as nearly as possible duplicating conditions throughout the area for which varietal recommendations are to be made. The need for several years' data before making recommendations of new varieties is universally recognized. In areas such as the Great Plains, which have extreme climatic conditions, it is frequently impossible to obtain yield data due to poor or irregular stands, wind erosion damage, late freezes, drought, hail, or other factors. Therefore, it is important that every effort be made to assure good stands and adequate moisture supplies by using fallow land for yield tests, provided yields obtained in this manner are comparable to yields on land previously cropped to wheat. In the Hays, Kans., area fallow is recommended 1 year out of 4 for wheat farms. Land, time, equipment, and financial resources available must, of necessity, be taken into consideration in deciding on a plan for making yield tests.

From 1921 to 1952, inclusive, variety plots of winter wheat at Hays, Kans., were 1/50th acre in size; a systematic design with two replications each was employed on fallow and land previously cropped to wheat. The average yield of all four replications was always reported as the yield of any variety for any particular year in Annual Reports, state-wide summaries, and varietal recommendations. This paper reports the results of an investigation of the relationship between yields of wheat on fallow and on previously cropped land. The purpose was to eliminate unnecessary duplication of effort if the results indicated a close relationship between yields of winter wheat on fallow and cropland.

No statistical correlations of yields on fallow and cropland have been found in the literature on wheat. However, several investigators have reported comparisons by analysis of variance or on the basis of relative ranks of yields on cropland and fallow.[4] Using analysis of variance for 8 wheat varieties grown for 9 years, 1938–46, on cropland and fallow at Woodward, Okla., Schlehuber reported statistically significant differences for varieties, for years, for methods (cropped or fallow), and for varieties × years, but not for varieties × methods.[5]

Casady reported 4 years' data for 13 wheat varieties and 9 years' data for 9 varieties on yield and test weight grown in 2 replications each of 1/50th acre plots on cropland and fallow at Hays, Kans.[6] He compared varieties by rank and concluded that for yield there was some trend for early varieties to rise in rank on cropland while midseason varieties appeared to decrease in rank. Rank of late varieties was not affected. For test weight he found no significant varietal difference in rank on cropland and fallow.

Haus at Akron, Colo., compared 9 wheat varieties over a 9-year period on fallow and following corn for test weight and yield.[7] No significant differences were found.

Reitz compared 5 varieties at North Platte, Nebr., over a 24-year period, 1925–48, on fallow and following corn.[8] Ranks in both groups were fairly similar with more variability being found following corn. Crop failures occurred in 6 years on cropland and twice on fallow. Reitz also compared 7 varieties during the period 1938–48 on fallow and following corn. Hail destroyed both plantings in 1943, and crop failures occurred after corn in 1940 and 1945 so these years were omitted from all comparisons. Of the 56 pairs of comparisons, 34 ranked the varieties the same—plus or minus one place—(roughly equal to one standard error of a difference). In several years differential response to lodging occurred on fallow but not after corn. Reitz concluded that a variety test on fallow rather than after corn would be preferred because better stands were obtained, failure was less frequent, higher yields were made, differences in lodging, certain diseases, and some other characteristics were more evident, field management was simplified, and fallow was an approved practice in the North Platte area. He noted, however, that farmers might justifiably prefer one variety over another for fallow or cropland under certain circumstances as, for example, a variety which might lodge on fallow but not on cropland.

EXPERIMENTAL METHODS

Data used in this study were accumulated at the Hays Station by A. F. Swanson during 1921–1951 and by W. M. Ross in 1952, on a varying number of winter wheat varieties grown in 1/50th acre plots in 2 replications each on fallow land and land previously cropped to wheat. Entire plots were harvested by a binder and threshed or combined. Data were unavailable or unreliable for 1923, 1931, 1934, 1935, 1937, 1939, and 1950 because of crop failures on cropland due mainly to drought, but in 1923 and 1931 hail destroyed crops under both systems. A systematic design was employed during the entire period, but analysis of variance was calculated as for a randomized block experiment.

Because varieties tested changed considerably over the 32-year period, statistical analyses could not be made on many entries

[1] Joint contribution from the Field Crops Research Branch, A.R.S., U.S.D.A., and the Fort Hays Branch, Kansas Agr. Exp. Sta., Manhattan, Kans. Contribution No. 88, Fort Hays Branch Exp. Sta., Hays, Kans. Received for publication Feb. 14, 1955.

[2] Assistant Professor, Kansas Agr. Exp. Sta.; and Associate Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A., respectively.

[3] Appreciation is expressed to Mr. A. F. Swanson, formerly Agronomist, U.S.D.A., for supplying most of the yield data used in this study and to Mr. Wayne L. Fowler, formerly Assistant Professor, Fort Hays Branch, Kansas Agr. Exp. Sta., for some of the calculations in the preliminary phases of this report.

[4] U.S.D.A. Report of the Sixth Hard Winter Wheat Improvement Conference at Stillwater, Okla. January 23–25, 1950, pp. 62–65. Permission granted by Directors of Experiment Stations in Oklahoma, Kansas, Colorado, and Nebraska to cite these results.

[5] *Ibid.*, p. 62.

[6] *Ibid.*, p. 63.

[7] *Ibid.*, p. 64.

[8] *Ibid.*, p. 65.

unless shorter periods of time were used. Consequently, 3 groups of varieties—8 for the 1921–30 period, 8 for 1931–41, and 9 for 1942–52—were analyzed individually by years and by groups of years. For any one group of years the varieties remained constant, though some varieties were tested during more than one period. Bartlett's test for homogeneity was used for testing groups.

Varying number of varieties were grown each year. For correlation studies within years, all entries were considered in order to give more comparisons. For intra-varietal correlations only varieties under test for 9 years or more were used. All correlation coefficients were simple or product-moment correlations. Meteorological data were obtained from records of the Hays station.

RESULTS AND DISCUSSION

The analysis of variance for the 25 years for which data were available are summarized in table 1. Varieties included in Group I were Kanred, Blackhull, Turkey, Kharkof, Harvest Queen, Nebraska 28, Nebraska 60, and Fulcaster. Group II included Turkey, Kharkof, Kanred, Blackhull, Tenmarq, Oro, Early Blackhull, and Cheyenne. Group III consisted of Turkey, Kharkof, Blackhull, Early Blackhull, Tenmarq, Pawnee, Comanche, Wichita, and Red Chief.

Table 1.—Summary of mean squares for 3 groups of wheat varieties grown at Hays, Kans., during the period 1921–1952.

Year	Mean Square				
	Variety	Method	V.×M.	Reps. in Methods	Error (V.×R. in M.)
	Group I				
1921	78.18*	104.04*	12.83*†	40.67**	4.21
1922	28.17	444.77**	5.32	9.60	15.59
1924	62.48**	26.10	17.64	85.42*	14.52
1925	9.20	1243.76**	16.89*	15.21	4.41
1926	15.80*	375.38**	5.52	14.12	7.17
1927	11.75*	0.13	4.28	7.34	3.74
1928	21.73	128.00*	41.10	43.89	19.16
1929	29.52*	727.71**	7.26*	4.96*	1.03
1930	35.27**	109.52**	11.90	1.44	4.83
D.F.	(7)	(1)	(7)	(2)	(14)
	Group II				
1932	8.19*	519.22**	1.95	0.04	1.91
1933	22.69*	5.12	8.67	90.70**	6.59
1936	15.59**	0.47	0.98	1.00	1.96
1938	21.55**	53.82**	2.69	5.88	1.76
1940	12.81**	21.45**	1.31	3.49*	0.91
1941	90.74**	0.00	6.91**	27.18**	0.21
D.F.	(7)	(1)	(7)	(2)	(14)
	Group III				
1942	22.46	695.20**	15.60	22.94	8.45
1943	24.24**	639.25*	4.56**	3.64**	0.56
1944	52.98**	9.41	6.98	5.28	7.55
1945	90.18**	17.50	10.87**	7.49*	2.03
1946	25.53	382.21**	15.34**	0.02	2.88
1947	13.85*	1211.04**	4.59	0.46	3.92
1948	77.49**	70.23**	10.30	2.62	5.55
1949	29.70**	17.50**	0.52	2.24	1.34
1951	40.17**	91.52**	6.56**	55.64**	1.20
1952	159.55*	734.41**	29.83**	2.37	6.48
D.F.	(8)	(1)	(8)	(2)	(16)

* Significant at the 5% level.
** Significant at the 1% level.
† When the V. × M. interaction was significant it was used as the variance for testing varieties and methods.

There was a lack of homogeneity of residual error variances within groups when tested by Bartlett's test for homogeneity.

A number of facts are obvious from table 1. The replications within methods interaction was significant in 9 years of 25 indicating rather variable growing conditions on the experimental area. High plot-to-plot variation within a given method of cropping, i.e. fallow or cropland, was often present with the result that residual errors (V. × R. in M.) were frequently rather large with a resulting loss of sensitivity for measuring differences by the variance ratio or F test. More replications almost certainly would have led to smaller mean squares and a more accurate measurement of varietal differences.

Differences between varieties were significant in 19 years of the 25 studied. This phase of the analysis is of minor importance as differences between varieties are expected. Many of the varieties studied have since been discontinued from testing.

The difference between methods of cropping was statistically significant in 18 years of the 25. Average yield for the varieties analyzed over the 25-year period was 25.6 bushels per acre on fallow and 22.3 bushels on cropland. This difference in favor of fallow would be larger if the data for the 5 years when a crop failure occurred on cropland were included. Average yields for all varieties on fallow were higher in 17 of 25 years and cropland yields were higher 8 years of 25 studied.

The variety × methods of cropping interactions were significant in 9 of 25 years. Data for years with significant interactions were further analyzed on the basis of maturity groups to determine the source of this interaction. Only one variety of a given maturity was available in certain groups so that it was impossible to calculate sums of squares between varieties within maturities in these cases. In 7 of the 9 years studied, the interaction of maturity × method of cropping was significant. In 1 year of 9 the interaction between early maturity × methods was significant. For midseason maturity, 4 of 9 years had a significant interaction. In the case of the late maturity group, in 3 of the 9 years there was a significant interaction with methods of cropping. The importance of differences between maturity groups in creating an interaction is clearly shown by these data.

When the meterological data and other pertinent information are studied, there is almost always a plausible explanation for this difference. In 5 of 9 years, rainfall was below average and in 3 years above normal. In 4 years of 9, temperatures were above normal, often much above. In 5 years of 9, in which interactions were significant, temperatures were below normal. Years in which there were below-average rainfall and above-average temperatures or vice versa were especially prone to interactions.

Other factors such as differential fall emergence, soil blowing, late spring freezes, diseases, differential lodging, and shattering of certain varieties appeared to be important in 1 or more years. There do not appear to be any consistent differences in yield on cropland and fallow of particular varieties within a maturity group; this would indicate that no one variety or group of varieties would respond relatively better on cropland than on fallow over a period of years. Such differences would be of considerable practical importance if discovered since it would then be desirable to recommend one group of varieties for fallow and another for cropland.

Correlation coefficients were calculated for each of the 25 years for which data were available between the mean yield of every variety grown on cropland and on fallow. Results of this comparison are shown in table 2. The coefficients were statistically significant in 20 of the 25 years. In 1924, yields were very high on both cropland and fallow due to adequate rainfall well distributed during the growing season. High plot to plot variation within a variety within a cropping method confused the situation. In 1925 it was drier and hotter than normal and yields on cropland were very low. As a result relative ranks of varieties varied considerably from fallow to cropland. The year 1928 was cool and wet, with lodging on fallow, but not on cropland; this caused considerable differences in relative rank of varieties on cropland and fallow. The year 1933 was hot and dry with heavy winterkilling in February. High plot-to-plot variation within a variety within a cropping method tended to obscure varietal differences. The year 1942 was wet and cool with lodging on fallow which led to differential varietal response on cropland and fallow.

To determine the effect of maturity on the correlation of yields on fallow and cropped land, each of the varieties which had been in the long-time summary was classified on the basis of the heading date as early, midseason, or late. The early group included Early Blackhull, Wichita, and Nebraska 28. The midseason group included Blackhull, Tenmarq, Pawnee, Comanche, and RedChief. Late varieties included Turkey, Kharkof, Kanred, Oro, Cheyenne, Nebraska 60, Harvest Queen, and Fulcaster. The average yield on fallow and the average yield on cropland of each maturity group were correlated with the following results: early, $r = + 0.789$; midseason, $r = + 0.826$; late, $r = + 0.868$. All of these coefficients are statistically significant indicating the close relationship of yields of a particular maturity group on cropland and fallow over a period of years.

Intra-varietal correlation coefficients were calculated for 16 varieties each of which was grown for 9 years or more for yields on cropland and fallow and are shown in table 3. In every case these yields were correlated, usually at the 1% level of significance.

Effects of rainfall and temperature on yields appeared to be pronounced in certain years. Therefore, correlation coefficients were calculated for yields for each of the three maturity groups on both cropland and fallow with mean maximum June temperature and rainfall from July 1 of the previous year to June 30 of the year in question. June is the month when kernel development usually takes place and when heat damage occurs most often. The following correlation coefficients were obtained:

Maturity group and cropping system	Correlation* coefficient for mean max. June temp. and yield	Correlation coefficient* for rainfall and yield
Early, fallow	−0.169	+0.350
Early, cropland	−0.232	+0.373
Midseason, fallow	−0.355	+0.413*
Midseason, cropland	−0.332	+0.424*
Late, fallow	−0.302	+0.359
Late, cropland	−0.366	+0.431*

* A correlation coefficient of $r = 0.396$ is required for the $P = 0.05$ level with 23 degrees of freedom.

Table 2.—Average yields and correlation coefficients of yields on cropland and fallow within years of all varieties on cropped and fallow grown at Hays, Kans., from 1921–1952.

Year	No. of Varieties	Average yield of all varieties (bu./A.)		Correlation coefficient†
		Fallow	Cropped	
1921	24	27.1	25.8	0.806**
1922	25	7.9	14.1	0.689**
1924	20	35.6	37.1	0.230
1925	18	18.9	5.9	−0.124
1926	21	14.9	21.1	0.463*
1927	24	9.4	9.0	0.641**
1928	26	38.1	36.4	0.007
1929	21	23.2	13.0	0.661**
1930	21	34.5	37.7	0.677**
1932	20	38.2	30.9	0.865**
1933	20	17.7	15.8	0.251
1936	19	27.7	27.8	0.868**
1938	17	26.9	23.8	0.962**
1940	17	15.9	14.0	0.834**
1941	19	32.1	31.0	0.972**
1942	17	27.6	19.4	0.330
1943	16	14.2	6.3	0.938**
1944	20	31.3	31.7	0.702**
1945	24	20.9	22.2	0.715**
1946	25	22.0	14.6	0.673**
1947	24	45.1	32.2	0.605**
1948	25	35.6	27.4	0.809**
1949	19	9.6	9.4	0.622**
1951	19	37.8	34.3	0.810**
1952	20	35.7	27.4	0.826**
Average		25.9	22.7	0.789**

* Statistically significant at the 5% level.
** Statistically significant at the 1% level.
† Correlation coefficients were not homogeneous when tested by the χ^2 test.

Table 3.—Varietal yields and intra-varietal correlations of yield on cropland and fallow for individual varieties of wheat for the years indicated at Hays, Kans.

Variety	No. Years	Average yield (Bu./A.)		Correlation coefficient
		Fallow	Cropped	
Early Group				
Early Blackhull	18	29.1	25.0	0.789**
Wichita	11	28.6	24.1	0.634*
Nebr. 28	10	24.8	22.2	0.728*
Midseason Group				
Blackhull	25	26.9	23.4	0.845**
Tenmarq	20	27.6	23.7	0.905**
Pawnee	12	29.1	23.6	0.911**
Comanche	12	28.4	23.1	0.843**
Red Chief	11	28.8	24.1	0.907**
Late Group				
Turkey	25	22.9	21.2	0.847**
Kharkof	25	24.5	21.2	0.852**
Kanred	22	25.1	21.8	0.760**
Oro	11	25.0	23.2	0.949**
Cheyenne	13	27.1	22.1	0.867**
Nebr. 60	13	22.9	22.7	0.781*
Harvest Queen	9	20.1	20.6	0.891*
Fulcaster	9	21.6	20.8	0.751*

* Significant at the 5% level.
** Significant at the 1% level.

The depressing effect of high temperature is indicated by the negative correlation coefficients which, while nonsignificant, are all approaching statistical significance. The greater effect of high temperature on later maturing groups is borne out by larger negative values of the correlation coefficients for these groups. When examined on a year-by-year basis, large increases in temperature are almost invariably associated with lowered crop yields unless moisture supplies are unusually favorable.

Effect of rainfall from the previous July 1 through June 30 of the current crop year on wheat yields on cropland and fallow was examined by means of correlation coefficients. Although only three of the six correlation coefficients were statistically significant, they all approached significance. The fact that the coefficient within a maturity group was always larger for cropland would seem to indicate the greater importance of seasonal rainfall for wheat grown on previously cropped land. Stated another way, wheat on fallow land seems less dependent upon rainfall during its growing season than wheat seeded on cropland.

The relationships, pointed out in this paper, warrant abandonment of wheat variety tests at the Hays station on cropped land. This already has become the practice of several other stations in the Great Plains. There is little room to doubt that well-conducted experiments adequately replicated will yield more information per unit of land and effort over a long-time period when on fallow than under both methods. Greater certainty of getting yield data and higher yields of seed are other advantages for using fallow land in addition to the advantages pointed out by other investigators.[9]

[9] *Ibid.*, pp. 62–65.

SUMMARY

1. Yields of winter wheat at Hays, Kans., on fallowed and previously cropped land were compared for a number of varieties for 1921–52. Seven years' data were omitted because of hail or drought damage.
2. Analyses of variance disclosed the following number of statistically significant comparisons out of 25 years' data: 9 for replications within methods; 9 for variety × methods interactions; 18 for between-methods comparisons; and 19 for between-variety comparisons.
3. Correlations within years of average variety yields on cropland and fallow were significant in 20 of the 25 years.
4. Intra-varietal correlation coefficients of yield on cropland and on fallow were statistically significant for all varieties.
5. When varieties were grouped for maturity, significant correlations were found between yields on cropland and on fallow for each of the groups, early, midseason, and late.
6. Correlation coefficients between average yields of a maturity group with mean maximum June temperature resulted in a negative correlation coefficient both for cropland and fallow, which approached but did not reach significance. Greater values were obtained for the later maturing groups indicating more yield depression with later maturing varieties.
7. Correlations between rainfall for the crop year and average yields of these maturity groups on cropland and fallow gave positive coefficients with three of the six being significant. All others approached significance.
8. Data presented in this paper warrant abandonment of wheat varietal testing on cropland at Hays, Kans., with more intensive testing on fallow.

Breeding Pensacola Bahiagrass, *Paspalum notatum*: I. Method of Reproduction[1]

Glenn W. Burton[2]

PENSACOLA Bahiagrass has become one of the most popular perennial pasture grasses in Florida and the southern part of the Gulf States. Its persistence, ability to grow on poor soils, excellent seeding habits and ease of establishment are responsible for much of its popularity. It was named by County Agent E. H. Finlayson (9), who found it growing wild in the vicinity of Pensacola, Fla., and concluded that it had been introduced in the ballast dumped on the low land adjacent to the old Perdido Wharf before 1926. The close similarity between Pensacola Bahia and an introduction, P.I. 149,303, received from Argentina in 1945 suggests that it also originated in that country.

Pensacola Bahia is taller, spreads faster, and has longer, narrower leaves than common and most other Bahia grass introductions (5). It is more frost resistant and winter-hardy but is also tougher and less palatable than these types. It is more resistant to ergot than any of these Bahias, but is susceptible to *Helminthosporium* sp. and *Rhizoctonia* sp. The seeds of Pensacola Bahia are smaller and germinate more readily without scarification than the seeds of the other Bahias but they also shatter much worse. Pensacola Bahia contains 20 somatic chromosomes, whereas all other Bahias examined to date, except introduction P.I. 149,303 (also $2n = 20$), have had 40 chromosomes as the 2n number. A breeding program directed toward the end of improving this grass was begun at Tifton, Ga., in the summer of 1941. It is the purpose of this paper to report the findings relative to the breeding behavior of Pensacola Bahiagrass.

[1] Cooperative investigations at Tifton, Ga., of the Field Crops Research Branch, A.R.S., U.S.D.A., and the University of Georgia Coastal Plain Exp. Sta. Contribution of the Department of Agronomy, University of Georgia Coastal Plain Exp. Sta. Published with the approval of the Resident Director as Journal Series Paper Number 33. Received Feb. 18, 1955.

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MATERIALS AND METHODS

Two lots of open-pollinated seed of Pensacola Bahiagrass from the Pensacola, Fla., area supplied the basic material for these investigations. The similarity of the progenies from these two lots of seed and observations of plants growing wild in the Pensacola area indicated that these lots of seed were an adequate sample of the ecotype.

Measurements for progeny behavior were based on individual seedling plants spaced 3 by 3 feet apart in the field. These plants were established by planting scarified seed in rows in flats, transplanting the desired number of seedlings to 2-inch clay pots and finally transplanting the potted plants to the field when they were large enough to insure their successful establishment. Overhead irrigation was used when needed. Selfed and open-pollinated plants of each clone were paired at random and replicated to enable direct comparisons and allow for statistical analyses of the results.

Self-pollination was accomplished by several different methods. Drinking straws were used for selfing in the field because panicles enclosed in glassine bags broke off unless the bags were supported with stakes. The drinking straws were slipped over the elongating panicles and folded at the top to close them just prior to anthesis. Very few panicles were broken with this selfing technique. Self-pollination in the laboratory was achieved by enclosing panicles (with a short piece of rooted stolon attached) in 3 by 2 by 14 inch glassine bags and immersing the rooted stolons in water. A numbered merchandising tag was attached to each bagged lot of heads to establish its identity and allow for the grouping of a number of clones in each gallon can of water. The bags were shaken each day during anthesis to favor pollination.

Mutual pollinations between pairs of 47 different clones were accomplished in the laboratory by enclosing two panicles of each of the two clones involved in a large glassine bag and immersing the rooted stolons in water (7). Care was taken to choose panicles of equal length and maturity (ready to flower). All bags were shaken each day during anthesis. Due to a lack of panicles, only 705 of the 1,081 possible mutual pollinations could be made.

The percentage seed set was ascertained by dividing the number of florets containing caryopses by the total number and multiplying by 100. A controlled air blast (4) was used to separate the empty florets from those containing caryopses.

RESULTS

A group of 43 Pensacola Bahia clones selfed in the laboratory by enclosing several panicles in large glassine bags developed an average of 6.0 caryopses per 100 florets. An average percentage seed set of 6.0% was obtained when another lot of 57 clones was selfed in the field by enclosing single panicles in jumbo waxed drinking straws (3/16 inch diameter by 8 inches long). The percentage seed set by these 57 clones dropped to 2.1 and 3.0% when single panicles were enclosed in small waxed drinking straws and small glassine drinking straws (1/8 inch diameter by 8 inches long), respectively. At the same time, these 57 clones developed an average of 89.5% of caryopses per 100 florets when open-pollinated.

Since the average percentage seed sets under jumbo straws in the field and under glassine bags in the laboratory were the same and since their distributions were similar, they were pooled to give the self-fertility distribution shown in table 1. These data indicate that a few clones of Pensacola Bahia are reasonably self fertile but that most of them are self sterile, setting less than 10% of seed.

Although the seed set of duplicate panicles sometimes varied considerably, the average seed set for the 4 panicles involved in each mutual pollination ranged from 40 to 80% in most instances. In only 4 mutual pollinations did all panicles involved set less than 5% of seed. Three mutual pollinations fell between 5 and 10% in seed set and 3 set more than 10% but less than 15% of seed on each head involved. Only one mutual pollination pair, involving clones setting more than 15% of seed when selfed, set as few seeds as the selfed clone. This pair had 1 clone in common with a mutual pollination pair that fell in the 5 to 10% class.

Although the inheritance of the self-sterility observed in Pensacola Bahia was not investigated, a compatibility relationship of the diploid personate type of multiple oppositional factors is suggested. According to this hypothesis (shown by Atwood (1) to be responsible for similar, but more extreme self-incompatibility relationships in white clover), sterility results because pollen tubes from grains carrying the same allelomorph as one of those in the pistil are unable to grow long enough to effect fertilization. Conversely, normal pollen tube growth and fertilization result when the pollen grain carries on allele different from those in the pistil.

If mutual pollinations giving panicles setting no more than 15% of seed or no more seed than the self-fertile clones (when selfed) be considered evidence of cross-incompatibility, it may be concluded that 11 clones carried the same S (self-sterility) alleles as 11 other clones. In three instances, the same clone was involved in two of these mutual pollinations; that is, A $\times$ B and A $\times$ C were both cross-incompatible. Although the third possible cross in these instances, B $\times$ C, was not made, the results suggest that three groups of three clones each carried the same S alleles. Thus, a minimum of 8 S factors could explain the cross-incompatibility observed in the 19 clones involved in these mutual pollinations. Had all other possible mutual pollinations been made and found cross-compatible as were the remaining 694, evidence for the existence of a minimum of 28 additional S alleles would have been established. Since only 65% of the possible mutual pollinations were made, this number must be reduced.

Atwood (2, 3) demonstrated the existence of 25, 26, 36, and 39 different S alleles in four lots of white clover. Emerson (8) found 34 different alleles for self-incompatibility in a natural population of 500 plants of *Oenothera organensis*. The results reported here indicate that many different factors (perhaps of the S type) are responsible for the self-incompatibility observed in Pensacola Bahia. They indicate further that most plants in a natural population will be cross-compatible, will intercross freely, and will set seed well.

Variability in Natural Populations

In the summer of 1941, 50 spaced, open-pollinated plants from a natural population of Pensacola Bahia were

Table 1.—Range in the ability of clones of Pensacola Bahiagrass to set seed when self-pollinated under bag.

	Percentage of florets to set seed										
	0 to 1.0	1.1 to 2.0	2.1 to 3.0	3.1 to 4.0	4.1 to 5.0	5.1 to 10.0	10.1 to 15.0	15.1 to 20.0	20.1 to 25.0	25.1 to 30.0	Total
Number of plants	12	9	15	10	10	25	10	7	1	1	100

Table 2.—The comparative performance of selfed and open-pollinated progenies of 13 Pensacola Bahia clones space planted in the field on May 26, 1944.

Clone Tested	Progeny performance in October, 1944								
	Plant yield in g.			Seed yield in g.			Leafiness rating‡		
	Self-pollinated	Open-pollinated	Sig. of diff.†	Self-pollinated	Open-pollinated	Sig. of diff.	Self-pollinated	Open-pollinated	Sig. of diff.*
1	211	180	*	7.50	6.50	NS	2.56	2.60	NS
4	84	120	*	2.68	3.07	NS	2.72	3.24	NS
6	120	140	NS	3.01	5.18	*	4.20	3.40	**
8	137	200	**	3.42	4.46	NS	3.00	3.35	NS
11	83	90	NS	2.96	2.95	NS	2.44	2.80	NS
12	138	137	NS	2.70	3.20	NS	2.30	2.76	NS
13	128	188	**	1.47	5.40	**	2.60	2.96	NS
16	94	155	**	3.57	4.32	NS	2.40	2.44	NS
19	126	189	**	3.20	5.01	**	2.48	3.56	*
20	140	151	NS	2.36	2.88	NS	3.16	1.60	**
22	55	145	**	.96	3.76	**	1.55	1.68	NS
23	32	111	**	.59	3.95	**	2.64	3.04	NS
24	77	105	NS	1.67	3.87	**	3.00	2.60	NS
Ave.	109.7	147.0	*	2.78	4.20	*	2.70	2.77	NS

† F values calculated for the progenies of each clone form the basis for the significance of the differences between the selfed and open-pollinated means shown above.
‡ Leafiness ratings ranged from 1 to 5, with 1 being the leafiest.
* Significant at 5% level.
** Significant at 1% level.

found to be extremely variable in plant type, seed production, rate of spread, leaf length, and leafiness. In addition to these characters, variations in forage production, disease resistance, seed shattering, and anther color were studied in natural populations totaling several thousand in later years. The great variation in all characters studied and the failure to find two identical plants in these studies indicate that Pensacola Bahia reproduces sexually and is highly cross-pollinated. This is an interesting contrast to common Bahia grass ($2n = 40$), which appears to be very highly, if not completely, apomictic in its mode of reproduction (6).

Inbreeding Effects

In the summer of 1943, an effort was made to produce selfed seed on 43 different Pensacola Bahia clones. Only 13 produced sufficient seed to allow for progeny tests in 1944. A comparison of the selfed and open-pollinated progenies (25 plants, in most instances) of the 13 clones revealed that all were highly variable. Individual plant data for three of the characters studied have been summarized in table 2. This summary shows that the first generation of inbreeding, on the average, reduced forage yields 25% and seed yields 34% but did not affect leafiness. Seven of the 13 clones produced significantly less productive progenies when selfed than when open-pollinated. A significant reduction in seed yield occurred in 6 of the 13 clones as a result of inbreeding. Only clone number 1 gave rise to a selfed progeny that outyielded its open-pollinated offspring and the difference in this instance barely reached the 5% level of significance. Attempts to carry some of these lines into the S_2 generation met with increasing difficulties. Many S_1 clones set too few seeds to give a suitable S_2 progeny and the few small S_2 progenies grown out showed additional reductions in vigor. Thus, it appears that inbreeding may be expected to reduce the vigor and yield of Pensacola Bahia, just as it has been demonstrated to do in many other highly cross-pollinated species.

SUMMARY

Pensacola Bahiagrass, *Paspalum notatum*, a vigorous, well adapted species that probably originated in Argentina, is a popular perennial pasture grass in Florida and the southern part of the Gulf States. Studies of the method of reproduction in this species reported here show that:

1. Most Pensacola Bahia grass plants are highly self-sterile. Fifty-seven clones that set 89.5% of seed when open-pollinated averaged only 6.0% seed set when selfed.
2. Six hundred and ninety-four of the 705 mutual pollinations made between 47 Pensacola clones set seed well, indicating that most clones are cross-compatible and that many factors (perhaps of the diploid personate type of multiple oppositional alleles) are responsible for its self-sterility. Thus, most plants in a natural population should be cross-compatible, should intercross freely, and should set seed well.
3. The extreme variability observed between many spaced clones in plant type, seed production, rate of spread, leaf length, leafiness, forage production, disease resistance, seed shattering, and anther color indicates that Pensacola Bahia grass reproduces sexually and is highly cross-pollinated.
4. The first generation of inbreeding 13 clones reduced, on the average, forage yields 25% and seed yields 34%, but did not affect leafiness. Thus, it appears that inbreeding may be expected to reduce the vigor and yield of Pensacola Bahia as it has been demonstrated to do in many other cross-pollinated species.

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Estimates of Genetic and Environmental Variability in Soybeans[1]

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RECENT studies on a number of characters of soybeans have been directed toward estimation of heritability, that is, the fraction of variance in phenotypic expression that arises from genetic effects. However, the different methods employed do not necessarily estimate the same thing. For example, variance and regression methods of estimating heritability of F_2 plant differences estimate the same thing only if all gene effects are additive. The nature of the selection units (plant, plot, mean of several plots, etc.) and sampling errors also influence greatly the magnitude of heritability estimates. Therefore, any meaningful comparison of the estimates obtained in different situations must include a careful evaluation of the methods and materials employed.

Heritabilities of individual plant differences were estimated by Weber and Moorthy (5), using data on spaced plants of four varieties and the F_1 and F_2 of three crosses involving the varieties. Variance among plants within the F_1's and the varieties was equated to environmental variance and subtracted from variance among F_2 plants to obtain estimates for genotypic variance. Heritability, the ratio of genotypic variance to F_2 variance, of yield was estimated to be 0, 13, and 60% in the three F_2 populations. The estimates for other characters were much more consistent from population to population and averaged as follows: flowering time, 75.6; maturity date, 75.3; period from flowering to maturity (fruiting period), 55.7; plant height, 62.0; seed weight, 54.3; and oil percentage, 54.7. Using the same method except that estimates of environmental variances were based only on variance among plants within the parent varieties, Mahmud and Kramer (4) estimated the heritability of yield and height in the F_2 of a varietal cross to be 43.4 and 40.6%, respectively. As pointed out by Weber and Moorthy, these estimates of genotypic variance contain variance due to genotype-environment interaction effects as well as genotypic variance.

Heritability of individual plant differences also may be estimated by the regression of progeny means on the performance of single plant parents. Bartley and Weber (1), using F_2 and F_3 parents, obtained estimates for yield, plant height, and maturity date, which averaged 15, 66, and 85%, respectively. Using the same method for F_2 parents, Mahmud and Kramer (4) obtained estimates of 5.9, 35.3, and 50.3% for yield, height, and maturity, respectively.

The regression of F_4 line means on F_3 line means estimates heritability of differences among the F_3 line means. Such estimates by Bartley and Weber (1) were 45, 62, and 92% and by Mahmud and Kramer (4), 77, 91, and 100% for yield, height, and maturity date, respectively. The F_3 and F_4 lines were evaluated in different years in the first case and each F_3 line and its F_4 progeny were evaluated in subplots of the same whole plot in the second.

The purpose of the present investigation was to estimate for two segregating populations of soybeans *(1)* genetic variance among F_3 lines in the F_4 and F_5 generations, *(2)* variance due to genotype-environment interactions, and *(3)* progress to be expected from selection.

MATERIALS AND METHODS

Field Experiments and Data Collected

Two populations of F_3 lines of soybeans were studied in the F_4 and F_5 generations. Eighty-nine lines resulting from the cross Roanoke × Palmetto, (population 1), and 64 lines from the cross N42-26 × Seminole (population 2) were evaluated. Each line traced to the seed of a randomly chosen F_2 plant. In both populations, lines in the F_4 generation were grown in 1950 and the F_5 generation in 1951. Population 1 lines were grown at McCullers and Statesville, N. C., and Monetta, S. C. (later referred to as Location 1, 3, and 2, respectively). Population 2 lines were grown only at McCullers and Monetta. Lines in each population were arranged in a randomized block design with 2 replications at each location in the 2 years, with a different randomization for each test. The plots were single, 19-foot rows, with 3-foot spacings between the rows. The seed were drilled at a spacing of 8 viable seed per foot of row. In 1950, growing conditions were good at all locations with above average rainfall that was well distributed throughout the season, except for a short period of drought late in the growing season at location 2. In 1951, conditions were good early in the growing season, but a severe late-summer drought occurred at all three locations. The plots at locations 2 and 3 were not harvested, and yield at location 1 was only 67% as high as in 1950.

A 16-foot section of each row was harvested for yield and chemical data were obtained from analysis of a 60-g. sample of beans from each plot. Characters measured on a plot basis were as follows: *(1)* time of flowering—recorded as the number of days from emergence to the date when half the plants in the plot were flowering; *(2)* fruiting period—recorded as the number of days from flowering to maturity; *(3)* maturity—recorded as the number of days from Sept. 1 to the date when all pods were ripe; *(4)* yield of seed in grams per plot (variances and means were converted to a bushels per acre basis for presentation); *(5)* seed weight—recorded as grams per 100 seed (based on weight of 200 seed per

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plot); *(6)* height in inches; *(7)* lodging (scored from 1 to 5, with 1 indicating almost all plants erect and 5 all plants lodged badly); *(8)* shattering (the plants remaining after the 16-foot section was harvested were scored from 0 to 5 approximately 2 weeks after harvest, with 5 indicating over 50% shattering; *(9)* protein percentage; *(10)* oil percentage; and *(11)* iodine number of the oil. Both oil and protein were computed on a dry weight basis. Measurements were taken on 10 randomly-selected plants per plot at locations 1 and 2 only and the 10-plant mean used as the plot value for the following: *(1)* number of branches; *(2)* number of nodes on main stem; *(3)* number of fruiting nodes on main stem; *(4)* average length of internodes of main stem; *(5)* number of pods per plant containing at least one fully developed seed; *(6)* percent of pods with one seed; *(7)* percent of pods with two seed; *(8)* percent of pods with three seed; *(9)* average number of seed per pod; *(10)* percent undeveloped ovules in pods containing one or more good seed; *(11)* number of seed per plant; *(12)* average number of seed per node; and *(13)* number of ovules per plant. Data on items 6, 7, 8, 9, and 10 were based on a sample of 20 randomly selected pods from each plant measured.

The primary purpose in taking much of the data on non-economic traits was to determine if any were closely correlated genetically with characters such as yield and oil content and, if so, whether heritabilities for any of these non-economic traits were great enough to make them useful as criteria for selection. The correlations will be presented in another paper.

Analyses of Variance and Estimation of Variance Components

Analysis of the data was predicated on the assumption that performance as measured in any of the characters considered was composed as indicated in the following equation:

$$X_{ijkm} = \mu + s_i + l_j + y_k + b_{jkm} + (ly)_{jk} + (sl)_{ij} + (sy)_{ik} + (sly)_{ijk} + e_{ijkm}$$

where X_{ijkm} is the measured value for the plot specified by subscripts,

μ is the population mean,
s_i is the genotypic effect for the ith line,
l_j is the effect of the jth location,
y_k is the effect of the kth year,
b_{jkm} is the effect of the mth block (of the randomized block field layout) at the jth location in the kth year, and
e_{ijkm} is a composite of remaining effects (including the plot effect, error due to sampling among the plants of a line, and error of measurement.)

Combinations of symbols refer to effects of interaction between factors indicated by the single symbols. For example, $(sl)_{ij}$ is the effect resulting from interaction between genotypes of the ith line and environments of the jth location.

Population variances will be symbolized by σ^2 and their subscripts will indicate the source. For example, σ^2_{sl} will signify variance of effects arising from interaction of lines with locations.

It is of prime importance to note that the genotypic effect, s, reflects the genotypic value of a line as an average for the population of environments of which the locations and years in which the data were obtained were considered to be a sample. It follows that σ^2_s is genetic variance (among lines) in average merit with respect to that population of environments. The special significance of σ^2_s arises from the fact that in practical breeding programs it is average genotypic value over the range of environments encountered in a region in successive years with which the breeder is concerned.

The data from each individual field trial (1 population at 1 location in 1 year) were examined separately and in various combinations by analysis of variance. Combined analyses involved *(1)* data for both years at 1 location, *(2)* data from 2 or 3 locations in 1 year, or *(3)* data from 1 location in 1950 and a different location in 1951. Data from the two populations were handled separately throughout. The form of variance analyses and associated mean square expectations are presented in table 1. Note from Section C of the table how the components of σ^2_p (progeny variance)[3] and σ^2_i (interaction variance) vary depending on the source of data analyzed and that only in the analysis of data from 2 years in which different locations were involved each year does the progeny variance provide an unbiased estimate of genetic variance, σ^2_s. Thus it is by sampling the environments that the estimate of σ^2_p becomes a more meaningful and realistic estimate of the variance of major interest, σ^2_s. Separate estimates of σ^2_s, σ^2_{sl}, σ^2_{sy}, and σ^2_{sly} could not be obtained from any one of the analyses described.

Estimates of variance components ($\hat{\sigma}^2_s$, $\hat{\sigma}^2_{sl}$, etc.) were substituted for the parameters in the following formulae to obtain estimates of heritability and expected genetic advance from selecting among lines:

$$\text{Heritability (H)} = \frac{\sigma^2_s}{\sigma^2_{ph}} \qquad [1]$$

where $\sigma^2_{ph} = \sigma^2_s + \dfrac{\sigma^2_{sl}}{l} + \dfrac{\sigma^2_{sy}}{y} + \dfrac{\sigma^2_{sly}}{ly} + \dfrac{\sigma^2_e}{rly}$ and is the phenotypic variance among the means of lines compared in r replications, l locations, and y years.

[3] Throughout the remainder of this paper σ^2_s will be used to designate progeny variance from which estimates of the variances due to the interaction of lines with locations, lines with years, and lines with locations and years have been removed, and σ^2_p will refer to progeny variance which contains the variance due to one or more of the interactions, in addition to the genetic variance.

Table 1.—Form of variance analyses and mean square expectation.

	d.f.	Mean square expectation
A. Analysis for data from one location in one year		
Replications	r−1†	——
Lines	p−1	$\sigma^2_e + r\sigma^2_p$
Error	(r−1)(p−1)	σ^2_e
B. Analysis for data from two or more environments*		
Environments	n−1†	——
Replications in environments	n(r−1)	——
Lines	p−1	$\sigma^2_e + r\sigma^2_i + rn\sigma^2_p$
Lines × environments	(n−1)(p−1)	$\sigma^2_e + r\sigma^2_i$
Error	n(r−1)(p−1)	σ^2_e
C. Composition of σ^2_i and σ^2_p as affected by data involved		
Data from	σ^2_i	σ^2_p
One location in one year	——	$\sigma^2_s + \sigma^2_{sl} + \sigma^2_{sy} + \sigma^2_{sly}$
Two or more locations in one year	$\sigma^2_{sl} + \sigma^2_{sly}$	$\sigma^2_s + \sigma^2_{sy}$
Two years at one location	$\sigma^2_{sy} + \sigma^2_{sly}$	$\sigma^2_s + \sigma^2_{sl}$
Two years, different location each year	$\sigma^2_{sl} + \sigma^2_{sy} + \sigma^2_{sly}$	σ^2_s

* Environments may differ with respect to location, year, or both year and location (see text).
† n, r, and p symbolize numbers of environments, replications per environment, and lines, respectively.

$$\text{Genetic Advance (Gs)} = \frac{\sigma^2_s}{\sigma^2_{ph}} \times k\sigma_{ph} \qquad [2]$$

where $k\sigma_{ph}$ is the selection differential expressed in phenotypic standard deviations. For the purpose of this paper, k was given the value 2.06, which is its expectation in the case of five percent selection in large samples from a normally distributed population.

EXPERIMENTAL RESULTS

Estimates of variance components for yield, height, seed weight, and percent oil obtained from data collected in four environmental situations are presented in table 2.

The relative size of the progeny and interaction variances for yield in population 1 indicated that a large proportion of the variability in this character was environmental, with σ^2_i being more than twice the size of $\hat{\sigma}^2_p$. In contrast, $\hat{\sigma}^2_p$ for yield in population 2 was greater than $\hat{\sigma}^2_i$ in two of the three environments that provided an estimate of these variances. The differences in the ratio of $\hat{\sigma}^2_p$ to $\hat{\sigma}^2_i$ for the two populations indicated that the relative yields of lines in population 2 were influenced less by the environments involved than those in population 1, but they do not provide an indication as to whether this was due to differences in the environments sampled in the evaluation of the two populations or the fact that relative yields in population 2 are actually influenced less by environmental differences.

The very small progeny variances for yield in both populations at location 1 in the extremely divergent years of 1950 and 1951 indicated that there was very little genetic variability in either population when average performance for the 2 years was considered, and the large interaction variances in comparison to progeny variances indicated extreme genotype-environment interactions in both populations.

Progeny variances for height, seed weight, and percent oil were more consistent in the four environments and the relative size of progeny variance to interaction variance was in general much greater than those for yield.

Estimates of heritability and genetic advance expressed in percent of the mean obtained from the combined analysis of data for locations and years are presented in table 3. In general heritability of yield in both populations was substantially smaller than that for the other characters measured on a plot basis; however, genetic advance for yield was greater than that for percent oil or protein, or iodine number.

DISCUSSION

Genotype-Environment Interactions

Accurate estimates of components of variance provide a basis for critically evaluating breeding and testing procedures. One cannot be sure that the estimates are accurate, and it is important to recognize their limitations when they are estimated from inadequate data, and to know that they are normally subject to substantial sampling errors.

Variance components presented in table 2 illustrate how erroneous conclusions may be drawn from estimates based on inadequate data. The estimates of σ^2_p are the best estimates of σ^2_s provided by the data in the environmental situations specified; however, σ^2_p estimated by data from one location and one year contains not only σ^2_s but σ^2_{sl}, σ^2_{sy}, and σ^2_{sly} as well. If the latter components are important, predictions based on $\hat{\sigma}^2_p$ for a single year and location would not be realized in future years or at other locations in the region. The interaction variances were especially important for yield of population 1 in this study. The genetic variability indicated by the data for 1 location and 1 year was reduced 71% when average performance over locations and years was considered. In contrast, over half the genetic variability for height, seed weight, and percent oil of both populations and yield of population 2 at 1 location in 1 year was maintained when mean performance over years and locations was considered, and the interaction variances were very small in comparison to those for yield of population 1. The interaction variances indicate the variability in the relative performance of genotypes in different environments, and their magnitude in comparison to genetic variances for various characters and different populations determine the need for replication in locations, years, and individual tests, in the accurate estimation of the means upon which selection is based.

Table 2.—Variance components for four characters measured in four environments.

Character	Population	Variance estimated by $\hat{\sigma}^2_p$				Variance estimated by $\hat{\sigma}^2_i$		
		2–3 loc. 2 yrs.	1 loc. 2 yrs.	2–3 loc. 1 yr.	1 loc. 1 yr.	2–3 loc. 2 yrs.	1 loc. 2 yrs.	2–3 loc. 1 yr.
		σ^2_s*	$\sigma^2_s + \sigma^2_{sl}$†	$\sigma^2_s + \sigma^2_{sy}$‡	$\sigma^2_s + \sigma^2_{sl} + \sigma^2_{sy} + \sigma^2_{sly}$§	$\sigma^2_{sl} + \sigma^2_{sy} + \sigma^2_{sly}$*	$\sigma^2_{sy} + \sigma^2_{sly}$†	$\sigma^2_{sl} + \sigma^2_{sly}$‡
Yield	1	1.72	0.09	2.34	5.99	3.57	1.57	5.55
	2	2.33	0.25	2.49	2.94	.28	1.99	1.47
Height	1	7.19	5.76	9.18	9.86	2.63	.00	2.64
	2	9.34	9.53	8.36	9.98	.39	1.40	.97
Seed weight	1	.53	.70	.95	1.03	.30	.29	.22
	2	4.06	3.61	4.66	4.47	.43	.39	.29
Oil %	1	.159	.228	.182	.245	.083	.042	.056
	2	.289	.304	.344	.368	.103	.018	.046

* Average of components from analysis of data from location 1, 1951 + location 2, 1950, and location 1, 1951, + location 3, 1950, for population 1; and from locations 1 and 2 only for population 2.
† From analysis of data from location 1, 1950 and 1951.
‡ From analysis of data from location 1 + 2 + 3, 1950, for population 1; and from location 1 + 2 for population 2.
§ Average of components from individual analysis of data from location 1, 2, and 3, 1950, and location 1, 1951, for population 1; and locations 1 and 2, 1950, and location 1, 1951, for population 2.

Investigations by Weiss *et al.* (6) and Kalton (3) indicated that the yields of F_3 lines at 1 location in 1 year were not indicative of the relative yields of the F_4 progenies at the same location the following year. However, Bartley and Weber (1) obtained correlations of 0.4 to 0.5 between the yield of F_3 lines obtained at 1 location in 1 year and the mean yield of two F_4 lines from each F_3 line at the same location the following year; and Mahmud and Kramer (4) found that when tested under identical conditions, the yields of bulk F_4 progenies showed a very high association with the yields of their F_3 progenitors. The results of Mahmud and Kramer indicate that the yield of an F_3 line should give a good indication of the yield to be expected from the F_4 progeny, and by comparison with results of the other workers, they suggest the importance of genotype $\times$ environment interaction variance.

The environmental differences varied greatly in the investigations mentioned above. Mahmud and Kramer designed their experiment so that the environments in which the F_3 and F_4 generations were grown were almost identical. Bartley and Weber stated that fairly normal conditions for growth were encountered in their study, while both Weiss, *et al.* and Kalton pointed out that the growing conditions differed considerably in the 2 years in which the F_3 and F_4 generations were grown. Large environmental differences in the present investigation produced results in agreement with those obtained by Weiss, *et al.* and Kalton, whereas smaller differences in environments yielded results similar to those obtained by Bartley and Weber. It is evident, therefore, that environmental effects account for much of the failure of the yields of soybean lines to be indicative of the yields of their progenies, and it seems likely that the failure of bulk population tests to give reliable predictions of yield potentialities of crosses as reported by Weiss, *et al.* (6) and Kalton (3) may have been due in part to cross $\times$ environment interactions.

All the investigations reviewed obtained essentially the same results with respect to height; i.e., the height of an F_3 line gives a good indication of the height of the F_4 progeny. In the present study the relative heights of F_3 lines in the F_4 and F_5 generations were more consistent from one environment to another than relative yields, and similar results were obtained for oil and protein percentage, resistance to lodging and shattering, maturity, iodine number of the oil, and seed weight. Thus it appears that early generation testing and the preliminary evaluation of advanced lines, in which the lines are selected on the basis of a replicated test at 1 well-chosen location in 1 year, should be effective for most of the important characters in soybeans except yield.

The difference in the effectiveness of selection for various characters has two important implications in soybean breeding. First, if a negative genetic correlation exists between yield and one or more other characters which are selected for, effective selection for the character other than yield in early generations and the ineffective selection for yield would result in discarding some of the better genotypes for yield, if selection pressure for the character in question were very strong. Second, if no serious negative genetic correlations exist, a breeding procedure is indicated whereby intensive selection for characters other than yield is practiced in the F_3 generation as the seed supply is increased for more extensive testing for yield in the F_4 and later generations.

Table 3.—Heritability, genetic advance, and means for 24 characters measured at two or three locations in two years.

Character	Population 1*			Population 2†		
	Heritability %	Gs in % of Mean	Mean	Heritability %	Gs in % of Mean	Mean
Yield	25.2	4.8	28.1	39.5	7.1	27.7
Height	61.4	9.6	45.3	80.9	14.1	40.1
Seed weight	68.0	8.8	14.0	92.1	19.7	20.2
Oil %	67.5	3.4	19.7	77.6	5.0	19.5
Protein %	38.9	1.5	42.2	82.8	4.3	43.7
Iodine number	70.4	1.4	132.5	81.8	1.7	134.9
Lodging	72.6	34.0	3.23	33.5	12.6	2.71
Days to flower	84.4	9.2	69.7	89.3‡	6.7	67.1
Days flower to mat.	76.6	6.9	85.3	43.1‡	2.9	83.4
Days Sept. 1 to mat.	71.0	5.4	59.7	71.0	6.3	61.8
Shattering	67.0	54.4	2.10	69.1‡	38.8	2.09
No. branches	37.7	16.9	2.88	72.6	49.9	1.92
No. nodes	69.2	11.1	18.3	63.5	7.2	19.8
No. fruiting nodes	51.5	9.5	12.3	19.0	2.3	12.7
Length of internode	73.6	11.3	2.35	72.2	10.8	2.03
No. pods per plant	21.7	5.7	43.6	50.5	13.1	36.5
1-seeded pods %	34.7	14.3	18.2	53.4	17.6	21.5
2-seeded pods %	38.2	4.7	71.2	65.3	7.9	68.6
3-seeded pods %	69.3	56.3	10.5	69.4	50.3	9.9
Av. no. seed per pod	59.5	4.1	1.92	59.4	3.7	1.88
Undeveloped ovules %	40.5	16.5	9.2	40.4	14.3	11.3
No. seed per plant	18.6	5.0	83.4	54.9	15.5	68.8
No. seed per node	48.9	15.1	4.59	64.4	18.7	3.49
No. ovules per plant	21.0	5.7	92.3	55.7	15.4	77.6

* Estimated from averaged components of variance from combined analysis of data for location 1, 1951, + location 2, 1950, and location 1, 1951, + location 3, 1950, for the first 10 characters and for location 1 and 2 only for the remainder.

† Estimates obtained from combined analysis of data for location 1, 1951, and location 2, 1950.

‡ Data on flowering time, fruiting period, and shattering are for location 1, 1950 and 1951, for population 2.

Heritability and Genetic Advance

Estimates of heritability as a ratio of genotypic to phenotypic variance may vary greatly depending upon the unit for which variance is considered. Since the plant breeder must consider genotypic value with reference to average performance over a population of locations and years, variances which are of major consideration to him are based on mean performance in an adequate sample of the population of locations and years involved. Although the definition of an adequate sample may vary with the genetic materials involved, the characters under consideration, and the population of environments involved, heritability of differences among the means upon which selection is based increases with an increase in the number of replications, years, and locations used in estimating the means. However, the opposite impression is frequently gained from the fact that estimates of heritability tend to decline with an increase in the number of locations and years in which the genotypes are evaluated. An explanation of this decline is readily attained from a consideration of the content of the variances involved. For example, progeny variance estimated from a single test (table 2) contains interaction variances in addition to genetic variance, the variance referred to in the definition of heritability, whereas progeny variance obtained from means of genotypes evaluated over two or more locations and years has an estimate of the interaction variances removed from it. Therefore, the data in the first case do not provide an estimate of heritability according to its definition but rather an estimate of the ratio of genetic variance plus interaction variances to phenotypic variance.

Heritability indicates the effectiveness with which selection of genotypes can be based on phenotypic performance. If heritability were 100% ($\sigma^2_s = \sigma^2_{ph}$) then phenotypic performance would be a perfect indication of genotypic value; but even in such a hypothetical situation, the heritability value in itself provides no indication of the amount of genetic progress that would result from selecting the best individuals. Heritability of 100% could result when both σ^2_s and σ^2_{ph} were 0.01, 1, 10, 100, etc., but genetic progress would increase with an increase in the variances. Therefore, the utility of estimates of heritability is increased when they are used in conjunction with the selection differential, the amount that the mean of the selected lines exceeds the mean of the entire group, and genetic advance is commonly predicted as the product of the heritability ratio and the selection differential.

Burton (2) has suggested that a genetic coefficient of variation $\left(\sqrt{\frac{\text{genetic variance}}{\bar{x}}} \times 100\right)$ together with a heritability estimate would seem to give the best picture of the amount of advance to be expected from selection. This statistic seems to have considerable utility in facilitating the comparison of genetic variability in various populations and characters and in some cases may be useful in estimating genetic advance. The formula for estimating genetic advance used in this paper can be reduced to a simpler form, $Gs = \frac{k\sigma^2_s}{\sigma_{ph}}$. If this is multiplied through by $100/\bar{x}$, this becomes

$$100\left(\frac{Gs}{\bar{x}}\right) = \frac{100\,k\,\sigma^2_s}{\bar{x}\,\sigma_{ph}} = k\left(\frac{100\,\sigma_s}{\bar{x}}\right)\left(\frac{\sigma_s}{\sigma_{ph}}\right)$$

This expression shows that the expected genetic advance from selection when expressed as a percent of the mean is the product of *(1)* the selection differential measured in terms of the phenotypic standard deviation, *(2)* the genetic coefficient of variation, and *(3)* the square root of the heritability ratio. Viewed in this way it is evident that the G.C.V. × k provides information concerning the maximum effect of selection, while heritability indicates how closely this maximum can be approached, with the maximum being attained only when the heritability ratio is unity. Therefore, unless interest is in the indicated maximum effect of selection or other information provided by the G.C.V., which would justify its computation, it seems to have little practical utility in predicting genetic advance.

It should be noted that Gs is defined with reference to genotypic values of the actual materials selected and may not be descriptive of the effect of selection measured in terms of genotypes derived by sexual reproduction from those materials. For example, the total superiority of lines selected on the basis of F_4 data may not be retained in the F_5 or F_6 generations. What should be anticipated in this connection depends on the nature of gene action, a matter which is presently under investigation but on which these data do not provide evidence.

SUMMARY

Twenty-four characters in 2 populations of F_3 lines of soybeans were studied in the F_4 and F_5 generations of the lines. The lines were evaluated at 2 or 3 locations in 1950 and at 1 location in 1951. Variance components are presented for yield, height, grams per 100 seed, and oil percentage; and heritability and genetic advance for average performance over locations and years are presented for all characters measured.

Estimates of genetic variance obtained in different environments were less consistent, and the estimates of genotype × environment interactions were higher for yield than for other important characters. The importance of genotype × environment interactions in reference to estimates of heritability and genetic advance are discussed.

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Effects of Two Cycles of Recurrent Selection for Combining Ability in an Open-Pollinated Variety of Corn[1]

D. P. McGill and J. H. Lonnquist[2]

CERTAIN weaknesses are inherent in any corn breeding method involving continuous self-pollination if the character under selection is quantitatively inherited. The genotype of each selfed S_0 or F_2 individual establishes a ceiling for the derived lines and, in addition, the rapid rate at which genes are fixed in the homozygous condition under self-pollination imposes severe limitations on the effectiveness of selection. These limitations can be circumvented to some extent by the use of recurrent selection, a breeding method in which inbreeding is held to a minimum. The method as used in modifying combining ability in corn consists of (a) intercrossing S_1 progenies of S_0 plants selected on the basis of their yields in test crosses and (b) the use of the population of intercrosses as foundation material for the next cycle. The procedure may be continued for successive cycles as long as sufficient genetic variability is present to allow effective selection. The ceiling in this case is the most desirable combination of genes possible from those present in not one, but rather a group of selected individuals. The probability of obtaining the one most desirable genotype is, of course, very low. The chance of obtaining satisfactory individuals should be increased, however, since a greater opportunity for recombination is present and, since the rate of inbreeding is reduced, genetic variability is held at a higher level which will permit more effective selection over an extended period.

The purpose of this investigation was to determine some of the effects of two cycles of recurrent selection for combining ability in an open-pollinated variety of corn. Three second-cycle synthetic varieties developed under the recurrent selection system and the open-pollinated variety from which they were derived were compared as sources of new lines. A group of advanced generation inbred lines developed under a system of continuous self-pollination in which selection at each generation from S_1 to S_5 was based on test-cross performance were compared with S_1 lines from the second-cycle synthetics. Finally, a study was made of the extent to which variability for combining ability had been altered under the recurrent selection system.

LITERATURE REVIEW

The general procedure now commonly employed in recurrent selection programs was first outlined by Jenkins (5) as a method for developing high-yielding synthetic varieties of corn. Variations in the general scheme and objectives have since been suggested by Hull (4) and Comstock *et al.* (1).

Lonnquist (9) developed two synthetic corn varieties by intercrossing S_1 lines from the upper and lower extremes of a distribution as determined by their yield in top crosses with Krug, the parental variety. The yield of the synthetic produced from high-combining lines was significantly greater than that of the synthetic from low-combining lines. Lonnquist (11) later compared the test-cross performance of plants from the two synthetics. The mean yield of test crosses from the two populations differed greatly when compared through the yield of the tester parent, WF9 × M14, included in the tests as a check. Sprague and Brimhall (13) obtained a shift of about 7 bushels per acre in mean top-cross yield through a single cycle of recurrent selection for combining ability in the Stiff Stalk Synthetic variety.

The recurrent selection method has also been employed in sweet-clover improvement. Johnson (7) found a single cycle of recurrent selection to be very effective in increasing general combining ability. The results indicate that the method may be effective in breeding forage crops.

If selection is for a character other than combining ability, the use of a tester is unnecessary. Recurrent selection has been successfully employed in modifying oil content of the corn kernel (13, 14) and in increasing resistance to *Helminthosporium turcicum* leaf blight in corn (6). In the latter case, classification prior to pollination was possible and thus a cycle could be completed in a single season.

MATERIALS AND METHODS

An open-pollinated variety, Krug yellow dent, 3 second-cycle synthetic varieties and 30 inbred lines developed from Krug, and the single cross WF9 × M14 were employed in this study. The three synthetic varieties have been designated $KH_{II(10)}$, $KH_{II(31)}$, and KL_{II}. The procedures used in the first cycle of their development have been given in detail by Lonnquist (9) and will be only briefly reviewed here.

Thirty-six S_1 Krug lines were evaluated in top crosses with the parental variety in 1944. The eight S_1 lines with the highest top-cross yields were selected as basic material for a high-yield synthetic. The seven S_1 lines with the lowest top-cross yields were used in the production of a low-yield synthetic. Fifty seeds from each of the component S_1 lines were composited to make up each synthetic. The two composites were planted in isolated increase plots in 1945. Seed (syn-1 generation) was harvested and planted in isolated plots to produce the syn-2 generation of the synthetics in 1946. The synthetics at this stage were referred to as KH_I syn-2 and KL_I syn-2.

In 1947, plants in KH_I syn-2 were self-pollinated and outcrossed to WF9 × M14. A yield trial of 152 of the test crosses was grown in 1948 (12). Ten S_1 lines whose test-cross yields exceeded the mean by two or more standard deviation units were selected as basic material for the second-cycle synthetic referred to as $KH_{II(10)}$. In this designation, II indicates the second cycle, and (10) the number of S_1 lines used in its production. Thirty-one S_1 lines, including the 10 mentioned above, whose test-cross yields exceeded the mean by one or more standard deviation units were selected as basic material for another synthetic, $KH_{II(31)}$. These synthetics were advanced to the syn-2 generation in basically the same manner described for the first-cycle synthetics.

Plants in KL_I syn-2 were self-pollinated and outcrossed to WF9 × M14 in 1948. Seventy-seven of the test crosses were grown in a yield trial in 1949 (12). Eleven S_1 lines whose test-cross yields were one or more standard deviation units below the mean were used as basic material for a second-cycle synthetic variety, KL_{II}. This synthetic was advanced to the syn-1 generation in an isolated plot in 1950.

Approximately 100 plants in each of the 3 second-cycle synthetic varieties and in Krug were self-pollinated and outcrossed to WF9 × M14 in 1951. On the basis of the amount of test-cross seed available, 76 test crosses from each of the populations were selected to be grown in the 1952 yield trial.

Self-pollination had been continued in the eight high- and seven low-combining lines used in making up the two first-cycle synthetics. Selection for combining ability was practiced within each of the lines, the selection at each generation from S_2 to S_4 being based on yield of test crosses with WF9 × M14 as tester parent

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(11). Subsequent to S_4 no further selection was practiced in the lines from low S_1's. One additional generation of selection within lines based on test-cross yields was carried out in the lines from the high S_1's. In 1951, 30 of the lines were used as pollen source in making test crosses with WF9 × M14 to be included in the 1952 yield test. Twenty-two of the lines had originated in the eight high-combining S_1 lines and had been selected on the basis of high test-cross yields at each generation. The other eight were derivatives of the low-combining S_1 lines and had been selected on the basis of low test-cross yields at each generation.

In order to compare the performance of hybrids between high- and low-combining synthetics with the performance of the parental variety and the synthetics as such, $KH_{II(31)}$ and $KH_{II(10)}$ were crossed with KL_{II}. Forty-plant paired rows were grown and crosses made reciprocally using bulked pollen.

The 1952 yield trial included the 76 test crosses from each of the 4 open-pollinated populations (Krug, $KH_{II(31)}$, $KH_{II(10)}$, and KL_{II}), 30 test crosses of the advanced generation lines, the 4 open-pollinated populations as such, and the 2 crosses between synthetic varieties. The test material was grown at Lincoln, Nebr., in a randomized complete block design with 6 replications using 2 by 5 hill plots.

There was some question as to parentage of two test crosses in the yield trial. One was from $KH_{II(10)}$ and the other was from KL_{II}. All calculations were made in duplicate, first with these items included and second with these items eliminated. Their elimination influenced most estimates only slightly, consequently all information presented on the test crosses from $KH_{II(10)}$ and KL_{II} was based on the remaining 75 items in each of these groups.

EXPERIMENTAL RESULTS

The average agronomic data recorded on the six groups of test crosses are presented in table 1. The means are of interest in that they may be considered estimates of the average performance in crosses with the same tester of a random sample of lines which could be derived from each source.

Considering the parentage of the synthetics, certain logical comparisons were made among the mean test-cross yields. The difference between the means of test crosses from $KH_{II(31)}$ and Krug, 5.1 bushels per acre, was highly significant ($t = 5.757$). Likewise, the difference between the mean of $KH_{II(10)}$ test crosses and that for Krug, 5.5 bushels, was highly significant ($t = 6.264$). The difference between the means of $KH_{II(31)}$ and $KH_{II(10)}$ test crosses, 0.4 bushels ($t = 0.609$) was not significant. The mean of the Krug test crosses was 2.3 bushels greater than the mean of the KL_{II} crosses. This difference was highly significant ($t = 2.820$). It is, therefore, apparent that the two cycles of recurrent selection have been very effective in altering combining ability in these populations.

The selection practiced in all phases of this study was based largely on yield in test crosses. No change, other than that due to random drift, would thus be expected in other characters unless they were associated with yield. In order to study any changes which had occurred in moisture in the grain at harvest, broken plants and dropped ears, the means for Krug test crosses were used as standards for comparison. The difference between the mean moisture percent for Krug and for KL_{II} test crosses was highly significant. This was no doubt due to the fact that Krug was near optimum in maturity for the Lincoln area and that selection for low yield had resulted in the retention of earlier types. None of the other differences observed was statistically significant.

The lines in the selfing series were derived from the same S_1 ears used in the recurrent selection series. The two methods were thus applied to comparable foundation material. At the time these programs were started, however, a critical comparison of the relative effectiveness of the methods was not contemplated. Therefore, no particular effort was made to keep the number of pollinations and volume of testing equal in the two programs. In the selfing series the test crosses of the S_2 plants were grown in 2 years and at 2 locations the second year. Test crosses of the S_3 plants were also grown at 2 locations but in a single year. In addition, whenever two or more sister-lines gave similar results they were retained and their progenies tested until, on the basis of progeny test crosses, a logical selection could be made. These procedures would increase the accuracy of evaluation of the lines for combining ability in that genotype-environment interactions would tend to be averaged out. As a result of the more intensive testing procedures, the total number of plots involved in the selfing series was greater than that in the recurrent selection program.

Table 1.—Agronomic data obtained on test-cross progenies using WF9 × M14 as a tester with S_0 plants of Krug open-pollinated variety, with S_0 plants of three Krug synthetics, and with inbred lines selected from Krug for high or low combining ability.

Source of test crosses	No.	Mean			
		Acre yield	Moisture	Broken plants	Dropped ears
		Bu.	%	%	%
$KH_{II(31)}$	76	97.5	11.4	4.6	1.3
$KH_{II(10)}$	75	97.9	11.1	3.3	1.1
"High" lines	22	97.1	11.2	2.7	1.4
Krug	76	92.4	11.2	3.4	1.3
KL_{II}	75	90.1	10.1	2.6	1.3
"Low" lines	8	90.5	10.5	2.1	1.2

The mean yield of the 22 test crosses involving the high lines was 97.1 bushels per acre. This does not differ significantly from 97.5 and 97.9, the means of the test crosses from $KH_{II(31)}$ and $KH_{II(10)}$. The mean test-cross yield of the 8 lines selected for low combining ability was 90.5 bushels per acre as compared to 90.1 for the mean of test crosses from KL_{II}. The difference was not significant. To this extent the results obtained by the application of the two methods appear similar. The greater amount of testing involved in the selfing series in this particular study may have been a factor in the results and should not be disregarded.

The data recorded on Krug, the three synthetic varieties as such, and the hybrids between the two KH_{II} synthetics and the KL_{II} synthetic are presented in table 2. $KH_{II(31)}$ and $KH_{II(10)}$ yielded 2.9 and 2.6 bushels, respectively, more

Table 2.—Agronomic data recorded on Krug, three synthetics, and two hybrids between synthetics.

Kind of corn	Acre yield	Moisture	Broken plants	Dropped ears
	Bu.	%	%	%
$KH_{II(31)}$	87.6	13.9	13	3
$KH_{II(10)}$	87.3	12.2	16	2
Krug	84.7	13.1	10	2
KL_{II}	69.4	11.1	5	2
$KH_{II(31)} \times KL_{II}$	86.1	12.6	5	3
$KH_{II(10)} \times KL_{II}$	84.5	10.8	8	1

than Krug. These differences are significant at the 10% but not at the 5% level. The difference between Krug and KL_{II}, 17.9 bushels, on the other hand, was highly significant.

The yield of the two hybrids between synthetics is of particular interest. Selection of the parental lines for the high- and low-combining synthetics was on the basis of yields in test crosses with the same testers. The effectiveness of this selection was apparent in the mean yields of test crosses from the low- as compared with the high-combining synthetics. Change in frequency of yield genes would be expected in both cases but the change would occur in opposite directions. As a result, regardless of the initial gene frequency, the hybrids between synthetics should be heterozygous at as many or more loci than either parent. If overdominance were relatively more important in heterosis than dominant favorable genes, the yield of the hybrids would be expected to be equal to or greater than that of either parent. This was not the case. Both hybrids were lower in yield than the better parent but the differences were not statistically significant.

The number of cycles in which efficient gains may be made in any character through recurrent selection will depend, to some extent, on the amount of genetic variability in the original population and the rate of loss of that variability with selection. Rapid loss of variability would limit the number of successful cycles and the ultimate advance possible under the system.

A visual comparison of the relative amounts of variability for combining ability in the four populations is available in the frequency distributions of test-cross yields presented in figure 1. That the Krug test crosses are more variable than those from the other populations seems rather apparent. Differences among the other distributions are, however, more difficult to detect and evaluate.

More reliable information as to the genetic variability in each population may be obtained through analysis of variance of the test crosses from each source. The mean squares may be utilized in estimating variance components (13). The component of variance attributable to differences among S_0 plants within a population is estimated by $s^2_p = \frac{M_2 - M_1}{r}$ where, M_1 is the error mean square, M_2 the S_0 plants mean square, and r the number of replications. The appropriate mean squares and s^2_p values for the test crosses from the three synthetics and Krug are presented in table 3. The calculation of s^2_p for the Krug test crosses was as follows: $s^2_p = \frac{5.411 - 0.521}{6} = 0.815$

Table 3.—Mean squares and genetic components of variance for yields of test crosses from the four sources, Krug, $KH_{II(31)}$, $KH_{II(10)}$, and KL_{II}.

Source of test crosses	Mean squares		s^2_p*
	S_0 plants	Error	
	(M_2)	(M_1)	
Krug	5.411	0.521	0.815
$KH_{II(31)}$	2.791	0.436	0.392
$KH_{II(10)}$	2.713	0.466	0.374
KL_{II}	1.806	0.337	0.245

* $s^2_p = \frac{M_2 - M_1}{r}$ where r is the number of replications.

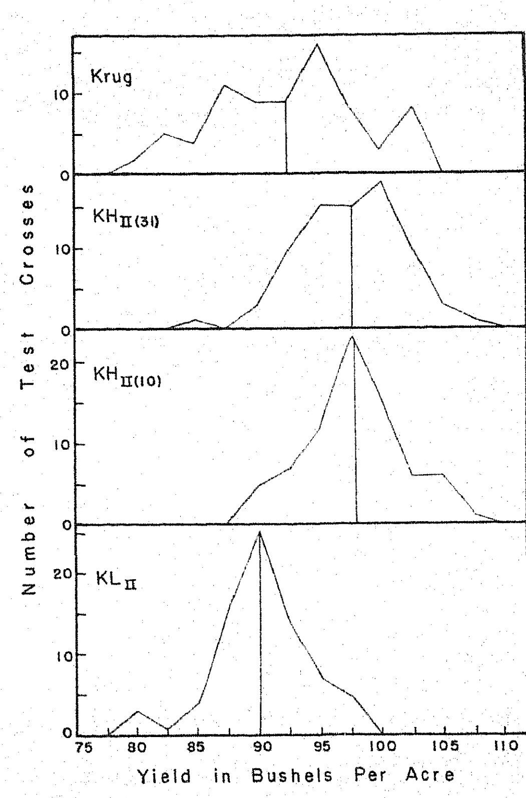

FIG. 1.—Frequency distributions of yields in bushels per acre of test crosses from Krug and from three second-cycle synthetics.

An approximate test of the difference between the s^2_p components of two populations is to treat s^2_{p1} minus s^2_{p2} as a normal deviate, T. Then, $T = \frac{s^2_{p1} - {}^2_{p2}}{\sqrt{V^2_{sp1} + V^2_{sp2}}}$ would be compared to T (0.05) = 1.96. The variance of s^2_p in the above equation may be estimated using the procedure given by Crump (2, 3):

$$V^2_{sp} = \frac{2}{r^2}\left[\frac{M_1^2}{F_1} + \frac{M_2^2}{F_2}\right]$$

where, F_1 and F_2 are the degrees of freedom for M_1 and M_2, respectively.

The s^2_p component for Krug was compared to that for each of the synthetics. In every case the component for Krug was significantly larger. Differences among the components for the synthetics, on the other hand, were not significant.

It is evident that considerably less variability in combining ability is present in the synthetics than in Krug, the parental variety. Several explanations for the loss in variability may be advanced. One could be that the selection practiced had been very effective in altering the frequency of yield genes. As gene frequency is shifted away from 0.5, toward either 0.0 or 1.0, genetic variability is reduced. Another explanation might be that the loss of variability was a direct result of inbreeding. It is likely that both of these are involved.

DISCUSSION

The results presented here indicate that two cycles of recurrent selection were effective in altering combining ability with the tester used. Definite increases in mean test-cross yields were obtained in $KH_{II(10)}$ and $KH_{II(31)}$ as compared with Krug, the parental variety. Likewise, the mean test-cross yield of KL_{II} was lower than that for Krug. It could be anticipated that if lines were developed from each population, those from $KH_{II(10)}$ and $KH_{II(31)}$ would, on the average, be higher yielding in crosses with WF9 × M14 than would lines from Krug.

The shifts in means obtained by recurrent selection were essentially equal to those obtained under a system of continuous self-pollination in which selection from S_1 to S_5 was based on test-cross performance in each selfed generation. The fact that similar results were obtained with a less intensive testing procedure in the recurrent selection series is evidence that this system was at least equal and perhaps superior in efficiency to selection within lines as a means of increasing frequency of favorable yield genes in this material. The results presented, however, are evidence only as to the effectiveness of the two methods up to this particular stage. As pointed out by Sprague and Brimhall (13) in reporting on a somewhat similar investigation, genetic variability would likely be very nearly exhausted after four or five generations of self-pollination. Little if any further advance in combining ability by selection within lines could be expected. On the other hand, by continuing with a group of selected S_1 lines from $KH_{II(10)}$ or $KH_{II(31)}$ additional gains might be expected under recurrent selection.

Reduction in genetic variability under recurrent selection was evident from differences in frequency distributions and genetic components of variance for test crosses from the three synthetics and Krug. As pointed out previously, this reduction may have been due to effective selection altering gene frequency, inbreeding, or a combination of the two. That gene frequencies have been altered is apparent from the shifts in mean test-cross yields and in the yields of the synthetics as such. It is not possible, however, to calculate the changes in gene frequency and the resulting changes in genetic variability.

Some loss of variability would be expected due to the fact that a limited number of S_1 lines were selected as parents in each cycle. The use of S_1 lines would result in the same degree of inbreeding as if the same number of selected S_0 plants had been allowed to mate at random. According to Li (8), the average rate of loss of heterozygosity in a randomly mating population of n monoecious individuals is $\frac{1}{2}n$ per generation. In this study the two cycles of recurrent selection would constitute two generations and the number of lines selected would determine the effective size of the population in each generation. Expected loss of heterozygosity attributable to inbreeding in the synthetics as compared to Krug were calculated. The values obtained were 7.8% for $KH_{II(31)}$, 10.9% for $KH_{II(10)}$, and 11.4% for KL_{II}. These values are not of sufficient magnitude to explain the observed reductions in variability.

Several factors might have been involved which could have increased the rate of loss of variability beyond that expected. For example, any deviation from random mating in the composites grown in isolation would have tended to increase inbreeding. Gutiérrez[3] reported that pollination frequencies in a group of nine interplanted stocks differed significantly from the expectations under random mating. The results were explained as being due, in part, to differences in date of tasseling, date of silking, number of plants shedding pollen, length of pollen shedding period, weight of pollen shed, and plant height. Even in a group of five stocks considered similar in flowering characteristics, the pollination frequencies did not meet the expectations under random mating.

Differences in yielding ability of the S_1 lines *per se* would also increase the rate of inbreeding in that the higher yielding lines would have a greater representation in the bulked progeny increase. In addition, any line especially potent so far as combining ability is concerned would likely be represented more frequently in the sample of S_0 plants selected for the next cycle than would less potent lines. This would have a favorable effect so far as a shift in the mean combining ability is concerned but would increase the rate of inbreeding. Sprague, Miller and Brimhall (15) calculated coefficients of inbreeding after single cycles of recurrent selection under conditions where randomness of mating and productivity of S_1 lines *per se* were not factors. Actual coefficients in five sets of material ranged from 4.4 to 13.6. If each of the S_1 lines selected in the first cycle had been represented equally in the sample chosen to make up the second cycle the coefficients would have been only 2.8. It is apparent that differences in prepotency can have great effects on the rate of inbreeding in a recurrent selection program.

Another factor of importance in this particular investigation was the viability of the S_1 seed used to produce the syn-1 generations in the first cycle. The S_1 lines selected to initiate the first-cycle synthetics were also continued in the selfing series. Of the seven lines selected for the KL_I synthetic, three failed to germinate in the hand-pollination nursery in 1945 when the first sample was to be taken in the S_1 lines (10). This was the season in which equal numbers of kernels from each of the S_1 lines were composited to produce KL_I. Low or complete failure of germination of one or more lines might not be noticed in an increase plot where a composite of lines had been planted. The low viability of certain lines undoubtedly resulted in an increased rate of inbreeding which was reflected by the loss of variability observed in the KL_{II} synthetic as compared with Krug. Although great differences in viability of the lines which made up the first-cycle KH synthetic were not reported, there is evidence that some differences did occur. Any such differences would have increased the inbreeding coefficient appreciably.

One of the main advantages assumed for recurrent selection is that genetic variability is maintained at a high level. This should permit more effective selection and also provide a greater opportunity for desirable new gene combinations to occur than is present under a system of continuous self-pollination. It is apparent from the results obtained in this investigation that unless appropriate precautions are taken, genetic variability may be dissipated at a rate far in excess of expectation. Rapid loss of variability would limit the number of successful cycles and the ultimate advance possible under recurrent selection.

The second method outlined by Sprague *et al.* (14) for minimizing inbreeding in a recurrent selection program is effective and provides for the determination of actual inbreeding coefficients where this information is desired. The $n(n-1)/2$ intercrosses among the n selected S_1 lines are grown as separate progenies and records of parentage main-

[3] Gutiérrez, Mario Gutiérrez. Factors affecting randomness of mating in isolated polycross plantings of maize. Unpublished Ph.D. thesis. Iowa State College library. 1952.

tained. The sample saved for the next cycle can be selected in such a way as to insure that each original line functioned equally or nearly so in the parentage of the selected sample. This procedure may reduce slightly the gain made in any single cycle but will provide variability for a maximum number of successful cycles. A somewhat different procedure is now used at the Nebraska station. A composite of the intercrosses among the selected S_1 lines is grown in isolation and one or more generations of random mating permitted before initiating the next cycle. This procedure should keep inbreeding near the minimum but the actual rate of inbreeding, which may be of importance in some studies, can not be determined.

SUMMARY

An open-pollinated variety of corn, Krug yellow dent, and three synthetic varieties developed by two cycles of recurrent selection for combining ability with Krug as the source material were studied. S_0 plants in each of the four populations were out-crossed to WF9 × M14 and the test crosses grown in a yield trial. It was concluded that the two cycles of recurrent selection had been effective in modifying combining ability and that the high-yield synthetics would be better sources of new lines than Krug.

Self-pollination had been continued in the S_1 lines intercrossed for the first cycle of recurrent selection. Selection at each generation had been based on test-cross yields. The average test-cross yield of 22 lines selected for high-combining ability did not differ significantly from the mean of test crosses from the high-combining synthetics. Similarly, the test crosses of eight lines selected for low combining ability gave yields essentially equal to the average yield of test crosses from the low-combining synthetic. Considering the intensity of testing in the two series, recurrent selection was considered equal and possibly superior in efficiency to the continuous selfing method.

The synthetics produced after two cycles of recurrent selection were less variable in combining ability than was the parental variety. The reduction in variability was greater than had been anticipated assuming the degree of inbreeding did not exceed that expected on the basis of the number of lines selected in each cycle. A part of the reduction in variability is attributed to a shift in gene frequency resulting from effective selection. A large portion of the reduction in variability is believed to be due to inbreeding. The increased rate of inbreeding is explained as possibly resulting from non-randomness of mating and differences in yielding ability, prepotency, and viability of the selected S_1 lines.

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Notes

THE INFLUENCE OF EARLY SPRING CLIPPING ON ALFALFA YIELDS[1]

IT IS desirable, in eastern Washington, to delay alfalfa hay harvest to escape unfavorable curing conditions. Normal delay of harvest after the first week of June results in alfalfa of poor quality because of over maturity. Cutting the alfalfa in early to mid-May permits delay of maturity into late June when weather conditions favor normal haycuring operations. The detrimental effect of such early cutting on hay yield and stand maintenance were unknown at the time this experiment was initiated. Jackobs,[2] working in the central Washington irrigated area, reported no loss of stand and only slight reduction in yield by an early spring cutting at the 4-inch height. This observation was in contrast to work done in other alfalfa growing areas of the United States.

Ten varieties of alfalfa were grown in a randomized plot arrangement of four replications. Each main plot was divided into two subplots. One cut at the normal maturity of alfalfa, the other was early cut at the 8-inch height stage (and discarded) and the second cutting made at the hay stage. These harvests were made in 1949 and 1950 (only one cutting is obtained from alfalfa in this area.) The third year (1951) all plots were cut June 13, to measure the residual effect of the early cutting treatment made the previous two years. Table 1 shows the results of that harvest. The yields of the early cut plots averaged only 83.5% that

[1] Received Jan. 26, 1955.
[2] Jackobs, J. A. The influence of spring clipping, interval between cuttings, and date of last cutting on alfalfa yields in the Yakima Valley. Agron. Jour. 42:594–597. 1950.

of those plots harvested at the normal hay stage. This yield was very similar to that secured for the 3 years as the early cut treatment yields averaged 84.4% of the standard cuttings for the 3 years. There was no evidence of any interaction between the early cutting treatment and the varieties used. No stand reduction was encountered as all plots and subplots maintained excellent stands during the length of the experiment. Even though the yield reduction was significant, the practice of early cutting apparently could be successfully employed without danger of stand loss or serious reduction in yield. The difference in hay quality due to better hay curing conditions encountered during late June, might well offset any loss in yield due to the early cutting treatment.—A. G. LAW *and* J. K. PATTERSON, *Associate Agronomists, Department of Agronomy, State College of Washington, Pullman, Washington.*

Table 1.—Cumulative effect of cutting treatments on alfalfa (1951).

Tons/acre	Normal treatment	Early cut treatment
Ladak (Montana grown seed)	2.97	2.54
Rhizoma	2.70	2.44
Ladak (Washington grown seed)	2.76	2.22
Meeker Baltic	2.56	2.28
Grimm	2.46	2.18
Ranger	2.51	2.02
Hardistan	2.49	1.96
Idaho Common	2.42	1.94
Cossack	2.39	1.95
Buffalo	2.11	1.66
Average	2.54	2.12

Variety L.S.D. 0.05 = 0.59
Cutting treatment 0.05 = 0.06

MACHINE FOR SUBSOIL SHATTERING AND DEEP PLACEMENT OF LIME AND FERTILIZERS[1]

RECENT investigations indicate that deep placement of lime and fertilizers encourages the kind of heavy root growth that can bring bigger yields, especially in a dry year. The shattering of subsoil destroys the "compaction pan" that develops near the surface of many good agricultural soils. In past investigations, no suitable equipment was available for thoroughly incorporating the lime and fertilizer with the subsoil.

A machine that not only shatters the subsoil, but thoroughly mixes lime and fertilizers with the soil to depths of 18 inches, has been built by the authors in cooperation with a manufacturing firm (see figure 1).

This machine is different from the usual chisel point normally used for subsoil shattering in that lime and fertilizer are distributed uniformly in the subsoil rather than being dropped in a narrow band behind the chisel. This is done by means of compressed air jets which blow the fertilizing and liming materials throughout the soil cavity formed behind the 12-inch sweeps. Figure 2 gives details of the subsoiler with fertilizer attachment.

It is believed that a thorough mixing of the lime and fertilizer with soil to a depth of 18 inches will encourage a well distributed root growth and thereby enable the plants to utilize the additional water and plant nutrients present in the deeper layer of fertilized and aerated soil.

Field trials, beginning in the summer of 1955, are being conducted to test the performance of this machine as regards effect on water relationships, yields of oats, corn and hay.—A. J. WOJTA *and* L. E. ENGELBERT, *Assistant Professors of Agricultural Engineering and Soils, and Soils Department respectively, University of Wisconsin,* L. L. PIERCE *and* J. L. DIAMOND, *Caterpillar Tractor Co.*

[1] Received March 3, 1955.

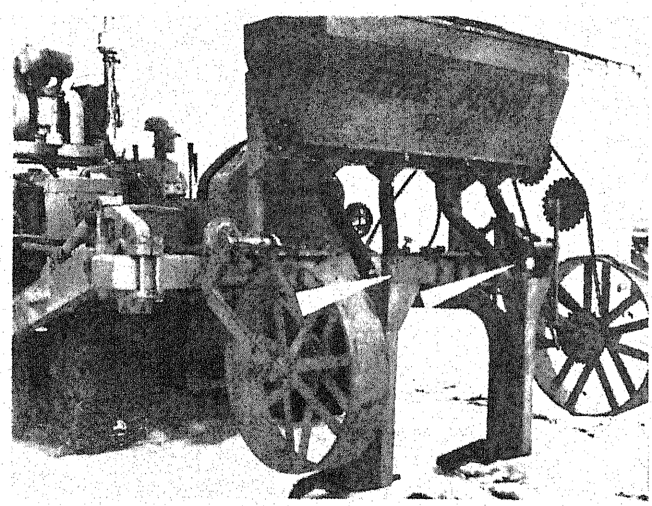


FIG. 1.—Deep tillage machine showing tool-bar mounted subsoilers with fertilizer attachment. Note air compressor on tractor hood and air lines (marked by arrows) leading down into the boots behind the subsoiler shank.

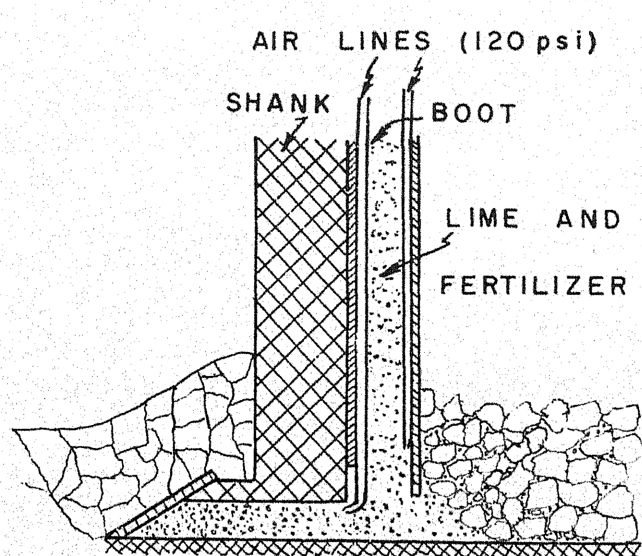


FIG. 2.—Cross sectional view of subsoiler showing the distribution of lime and fertilizer, by means of the air jets, throughout the shattered subsoil.

THE INFLUENCE OF TIME OF THINNING CORN AND THE NUMBER OF PLANTS REMOVED ON THE GRAIN YIELD OF THE REMAINING PLANTS[1]

THE use of small plots or a limited number of plants in corn cultural experiments is usually both necessary and desirable. Because of this, it is essential that the plant competition within and between hills be equalized insofar as possible by having a perfect stand. The method most often used to minimize competition is planting thick and later thinning to the desired number of plants.

Different investigators use various methods and different dates for the thinning operation. This paper presents limited experimental data collected at Urbana, Ill., on the influence of time of thinning and number of plants removed on the grain yield of the remaining plants.

The spacing between rows and hills within rows was 39.6 inches. Individual plots were 2 hills wide and 10 hills long. The variety of corn used was U.S. 13. The tests were located on heavy clay loam of good texture and high fertility.

The planting rates used were 3, 4, 5, and 6 kernels per hill. Every planting rate plot was adjacent to a check plot planted at the rate of two per hill. Therefore, every third plot was a check plot. Six comparisons or replications for each treatment were included. Thinnings were made on 4 dates, at which time the plants averaged 7, 20, 41, and 70 inches in height to the tip of the top leaf extended.

In the thinning operation, the stand was reduced to correspond to the stand of the adjacent check. For example, when a plant or hill was missing in the check plot, the identical situation was left in the adjacent thinned plots. The thinning method used for each date was selected as the most appropriate and easiest method considering the size of the corn plant (see bottom of figure 1).

Grain yields were calculated on the basis of 15.5% moisture. In the compilation and analysis of the data, the deviations between the treatment plots and adjacent check plots were used. The mean yield of all check plots (planted 2 kernels per hill or 8,000 per acre) was 70 bushels.

Thinning or removal of plants from individual hills of corn in general resulted in a lower grain yield for the remaining plants. This yield loss increased as the number of plants removed increased and as the plant height at time of thinning increased. The yield loss when 2, 3, and 4 plants were removed per hill showed a positive linear relationship to the plant height at the time of thinning (figure 1).

Yield reductions from thinning might be attributed to two sources: the amount of nutrients taken up by the thinned plants before their removal, and the mechanical disturbance to the root system of the remaining plants. Under certain conditions the latter injury might have the greatest influence. In root pruning experiments, Spencer[2] has reported an 18% grain loss when severe root pruning was employed. However, the methods used for the last two thinnings as reported in the present study are not believed to have disturbed the remaining plants. The deviation trends, therefore, seem to indicate that the nutrients removed by the thinned plants before their removal limited the production of the remaining plants. Davidson[3] analyzed plants thinned at different dates and suggested this possibility.

An analysis of variance of the yield deviation from the undisturbed adjacent plots showed highly significant differences for both height and number of plants removed. Most of the difference for height could be attributed to a single comparison of 70-inch *vs.* 7, 20, and 41-inch heights." Also, in considering number of plants removed, most of the difference could be accounted for by the comparison, 1 and 2 plants *vs.* 3 and 4 plants.

It should be pointed out, however, that in most corn experiments the germination is good and it is not a general practice to plant 3 and 4 extra kernels in each hill. Usually only 2 extra kernels are planted per hill and sometimes only 1. At these two planting rates the effect of height at time of thinning was not so serious.

Although cost analyses for the different methods of thinning were not kept, the method of breaking the plants off below the growing point is the easiest, most rapid, and generally disturbs the other plants in the hill to a lesser degree. It is certain that the morale of the thinning personnel is higher when plants are large. At an early age more care must be exercised in counting and the accidental removal of too many plants is more likely to occur. The latter is particularly true when the soil is dry. Insects or

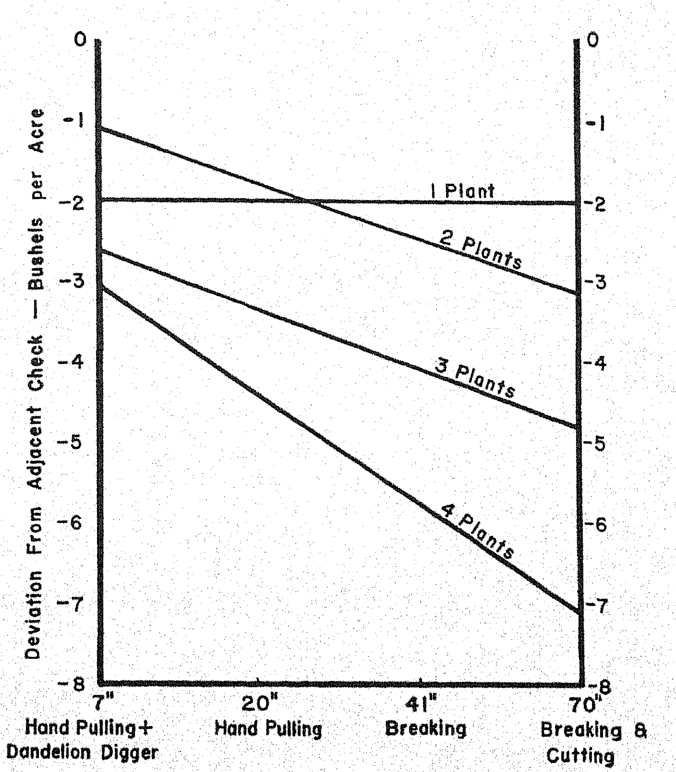


FIG. 1.—The influence of number of corn plants removed per hill and the height of the plants at time of removal on the grain yield of the remaining plants, Urbana, Illinois, 1950–1951.

[1] Contribution from the Department of Agronomy, Illinois Agr. Exp. Sta., Urbana, Ill. Published with approval of the Director of the Ill. Agr. Exp. Sta. Received March 5, 1955.

[2] Spencer, J. T. The effect of root pruning and prevention of fruiting on the growth of roots and stalks of maize. Jour. Amer. Soc. Agron. 33:481–489. 1941.

[3] Davidson, J. Removal of plant food in thinning corn. Jour. Amer. Soc. Agron. 18:962–966. 1926.

even cultivation mishaps are more likely to reduce the final stand of early thinned corn than late thinned corn.

On the basis of the results presented and reasons cited, it is the general practice at the Illinois Experiment Station to allow corn to approach knee high before thinning. A sideward jerk at this time breaks the plant at about the ground level and below the growing point. The optimum time to do this is in the early morning when the plants are brittle. Perhaps on soils of lower fertility when nutrient competition between young plants would be greater, the loss in final grain yield of the remaining plants might be different from the results presented herein.—J. W. PENDLETON, *First Assistant in Crop Production, and* G. H. DUNGAN, *Professor of Crop Production (now on leave at Alahabad Agr. Inst., India), Illinois Agr. Exp. Sta.*

VARIABILITY IN THE PERFORMANCE OF ALFALFA SEED LOTS SOLD AS "DAKOTA 12"[1]

IT HAS been apparent for a number of years that alfalfa seed sold as Dakota 12 has given highly variable results. Memories of good fields have perpetuated the demand for seed sold under this label. The Nebraska Station has recognized Dakota 12 only as a descriptive term used in much the same manner as are the terms Dakota Common and Nebraska Common. Effective July 1, 1953, clarification of existing legislation prohibited the sale in Nebraska of any lots under this label.

Limited facts available on the origin of Dakota 12 and yield results of Dakota 12 in comparison with Grimm and Turkestan are reported[2] as follows:

1. Numbers were assigned by early South Dakota station workers to various lots received for observation. A lot of Common received from a grower in western South Dakota was given South Dakota Number 12.

2. In preliminary yield tests (one year's results at Highmore) it yielded about 1,400 pounds of field-cured hay per acre less than Grimm. This lot proved to be hardy but the South Dakota Station did not release this lot of Common as a variety.[3]

It appears, therefore, that producers and handlers of alfalfa seed have perpetuated use of the term "Dakota 12" since there was a continuing demand for hardy alfalfa. Although the term may have originally applied to seed from hardy alfalfa produced in a given region, it was apparent in later years that there was a high degree of variability in the performance of seed sold under this label.

In 1952 and 1953 seed samples were obtained from 42 lots sold as Dakota 12. These samples were obtained for test purposes through the courtesy of the U. S. Department of Agriculture and the Nebraska Department of Agriculture. State of origin, names and addresses of dealers handling the lots, and location at which sold were obtained for nearly all samples. A two-replicate field observation planting of these lots and samples of varieties was made at Lincoln, Nebr., in the spring of 1953. Each plot consisted of a single row 16 feet long. The seeding rate was 12 pounds per acre. Seedlings from these lots were also tested for cold reaction in a controlled freezing test in 1953 and for wilt reaction in a controlled greenhouse wilt test in 1954. Controlled cold and wilt tests are standardized procedures used in the alfalfa breeding program and have been found by repeated use to give results of high predictive value. Data for cold reaction reported in table 1 are based on an average of 12 replications of about 25 plants each whereas data for wilt reaction are based on an average of 3 replications of about 75 plants each. Percent healthy plants (free of infection) and percent surviving are used as criteria in the wilt and cold tests, respectively. Both cold and wilt reaction are expressed in terms of percent of certified Ranger with Ranger as 100.

Table 1.—Performance of alfalfa seed lots sold as Dakota 12.

State		Cold reaction	Wilt reaction
Of origin	Of sale	% Ranger	% Ranger
Colorado	Nebraska	118	47
Minnesota?	Illinois	105	18
Nebraska	Ohio	82	65
	Illinois	72	88
	Nebraska	90	71
	Nebraska	105	53
	Nebraska	90	82
	Nebraska	95	71
	Nebraska	120	18
	Nebraska	98	41
	Nebraska	80	35
	Nebraska	75	94
	Nebraska	82	41
	Nebraska	102	47
	Nebraska	108	65
North Dakota	Illinois	128	29
	Missouri	132	53
South Dakota	Nebraska	122	29
	Illinois	72	53
	South Dakota	78	94
	Iowa	82	41
	Illinois	110	53
	Illinois	120	47
	Illinois	108	29
	Minnesota	92	71
	Minnesota	85	82
	South Dakota	100	35
	South Dakota	100	35
	South Dakota	95	59
	Illinois	88	59
	Illinois	115	18
	Illinois	95	59
	Illinois	112	65
	South Dakota	80	82
	Nebraska	88	35
	Nebraska	102	100
	Illinois	105	53
	Missouri	102	71
Washington	Nebraska	82	88
Wyoming	Nebraska	118	35
Unknown	Illinois	80	65
Unknown	Illinois	100	65

Twenty-one of the samples were as hardy or hardier than Ranger as determined by the controlled cold test. The other 21 samples varied from 72 to 98% as hardy as Ranger. The range in hardiness, from 72 to 132% of Ranger, was

[1] Contribution from Field Crops Research Branch, A.R.S., U.S.D.A., in cooperation with the Nebraska Agr. Experiment Station. Published with the approval of the Director as Paper No. 701, Nebraska Agr. Exp. Sta. Received March 7, 1955.

[2] South Dakota Agr. Exp. Sta. Bul. 163, 1916.

[3] Correspondence from M. W. Adams, Agronomist, South Dakota Agr. Experiment Station.

60%. One of the samples had the same wilt reaction as Ranger, whereas 41 samples had a wilt reaction of 18 to 94% of Ranger as determined by the controlled wilt test. The range in wilt reaction from 18 to 100% of Ranger was 82%. A sample of South Dakota origin had the same wilt reaction and essentially the same cold reaction as Ranger. Field observation notes indicated that this sample resembled Ranger very closely.

Field notes were taken in 1954 on the two-replicate observation planting made in 1953. Winterkilling was negligible in Dakota 12 samples and in the entire test. In the same test, India and Argentina samples had a stand of 92 to 97%. Spring habit-of-growth, rate-of-recovery after second cutting, and fall habit-of-growth were observed and rated on a basis of 1 to 9, with 1 being erect in growth-habit and fastest to recover and 9 being prostrate in growth-habit and slowest to recover. Averages observed for the various samples of Dakota 12 lots were as follows: spring habit-of-growth scores varied from 3.0 to 5.0; fall habit-of-growth from 3.0 to 5.5; rate-of-recovery from 4.0 to 5.5. Summer drought probably prevented maximum expression of differences in rate-of-recovery. Although the ranges for growth-habit and rate-of-recovery scores reported above were small, the extremes of the ranges nearly represent the differences found between Buffalo and Grimm.

Simple correlations between field notes and data obtained in controlled tests were initially studied by means of scatter diagrams. It was apparent from the diagrams that no correlations of sufficient magnitude for predictive purposes existed. Therefore, no computations were made. Correlation between cold and wilt reaction in independent controlled tests of short duration would not be expected. Field notes taken in one year, which perhaps was atypical, were not expected to be highly correlated with controlled tests. It is of interest in the case of cold reaction in controlled tests vs. fall growth-habit that 6 of the 7 lots with a fall growth score of either 3.0 or 3.5 were less hardy than Ranger with an average score of 4.8.

Thirteen of the samples studied were produced in Nebraska and 21 were produced in South Dakota. Variability among samples from each of these states is very nearly the same as the total variability observed for all states. Thus Dakota 12 as produced in South Dakota and Nebraska would most likely give highly variable farm results.

Cold and wilt tests have been conducted periodically to determine the range in reaction within lots of the same variety produced under the certification program. Slight differences have been found that are not associated with region of production, seed class, or any known factor. The range of differences between lots within a seed class and within a given variety has been small. Twenty-eight lots of Ranger were included in the 1953 field planting. Small differences in spring and fall growth-habit and in rate-of-recovery were found. The range of such differences was smaller than that found for the Dakota 12 samples.

The variable performance of 42 lots of alfalfa seed sold as Dakota 12, as measured in controlled cold and wilt tests, indicates that there is little likelihood of getting uniform performance from various lots of seed represented to be of this identity.—W. R. KEHR, *Research Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A., Nebraska Agr. Exp. Sta.*

STOLONIFEROUS CRESTED WHEATGRASS[1]

SOME species of the Agropyron genus normally without rhizomes may rarely produce them, according to Hitchcock. Such a rhizomatous strain, P.I. 109102, closely related to, or within the normally non-rhizomatous species crested wheatgrass, was collected by the Westover Enlow

[1] Received March 2, 1955.

FIG. 1.—A new crown formed on an outside culm of a crested wheatgrass plant. It may have arisen by proliferation of an anomalous spikelet below the spike.

FIG. 2.—A crested wheatgrass plant showing two new plantlets formed by stolons.

expedition in 1934. No instance, however, of stolon-forming crested wheatgrass has previously been reported.

In October 1954, this phenomenon was observed in the spaced plants which had been transplanted into the breeding nursery at South Dakota State College the previous May. These plants had been derived from selections of Standard crested wheatgrass obtained from fields in South Dakota. The new crowns appeared to have arisen by axillary budding at the last culm internode immediately below the spike, as shown in figure 1, but may possibly have arisen by proliferation of an anomalous spikelet formed on the culm below the spike. These buds arose on the culms near the outside of the clump so that those which came in contact with the soil by reason of the added weight of the growth near the end of the culm, formed roots and established new plants. An instance of the formation of such new plants is shown in figure 2. This phenomenon appeared simultaneously in a number of plants within this population. Since its appearance coincides with the genotypic similarity of the progenies concerned, it is highly probable that the character could be fixed within a variety. This character would have value as a secondary means of propagation of outstanding genotypes within a population and would therefore help to ensure the persistence of established stands.

Axillary budding somewhat similar to that described here has been illustrated by Arber[2] for *Festuca elatior, F. ovina Phleum pratense, Holcus lanatus, Lolium perenne, Agropyron repens, Dactylis glomerata, Agrostis palustris, and Glyceria maritima*, all of which do not normally have this character present in their populations; but no definite indication was given as to whether this character was wholly a product of the particular environment or whether it might have arisen as a mutation.—J. G. Ross, *Agronomy Department, South Dakota State College, College Station, S. D.*

[2] Arber, Agnes, The Gramineae. Cambridge University Press. 1934.

Bylaws of the Regional Branches of the American Society of Agronomy

CONSTITUTION OF THE NORTHEASTERN BRANCH OF THE AMERICAN SOCIETY OF AGRONOMY

As Revised, July 1953

ARTICLE I

Name: The name of this organization shall be the Northeastern Branch of the American Society of Agronomy.

ARTICLE II

Object: The object of the Society shall be the increase and the dissemination of knowledge concerning soils and crops and the conditions affecting them.

ARTICLE III

Membership: There shall be two kinds of members, active and associate.

Active membership in the Branch is dependent upon membership in the American Society of Agronomy. It may be secured by written endorsement of one active member, together with approval of the President and Secretary and payment of the annual dues.

Associate membership is obtained by payment of the annual dues to the Northeastern Branch, and carries all privileges as outlined in the constitution of the National Society.

ARTICLE IV

Officers: The *officers* shall consist of a President, a Vice-President, and a Secretary-Treasurer. The duties of the officers shall be those usually pertaining to their respective offices. The term of the President and Vice-President shall not be extended beyond two consecutive years, but they may be re-elected after others have served in the same positions.

One *Director* and one *Alternate* shall represent the Northeastern Branch in the National Society. They shall be elected from the active membership of the Branch and shall hold office for two years.

The *Executive Committee* shall consist of the three officers, the immediate Past President, and both the Director and the Alternate, and shall act upon all matters arising between annual meetings of the Branch.

ARTICLE V

Nomination and Election of Officers: The nominating committee shall suggest from the membership of the Branch two nominees for the following: President, Vice-President, Secretary-Treasurer, and in alternate years, beginning in 1953, two for Director and two for Alternate.

ARTICLE VI

Meetings: When not determined by vote of the Society, the time and place of meetings shall be decided by the Executive Committee.

ARTICLE VII

Amendments: This constitution may be amended by a two-thirds vote of the members present at any regular meeting, announcement of the proposed amendments having been made at least ten days before each such meeting. The Executive Committee may propose amendments at any time between meetings and the same shall be accepted or rejected by a two-thirds vote of the members who mail their ballots within thirty days after the notice of the proposed amendment was sent to them. Any ten members may initiate a proposed amendment, which shall then be submitted by the executive committee to a vote of the Society.

BY-LAWS

1. All active and associate members of the American Society of Agronomy residing or employed in the Northeastern Region are granted membership in the Branch without payment of dues to the Branch.

2. Associate members in the Northeastern Branch shall pay annual dues of $1.00.

3. A registration fee of $1.00 shall be paid by all who attend the Branch Meetings, except that the Executive Committee may waive the fee when the balance in the treasury is in excess of $100.00.

4. Full voting privileges shall be extended to both active and associate members of the Branch.

5. One meeting of the Branch shall be held every year, if practicable.

6. A quorum at any meeting shall consist of a majority of those registered at that particular meeting.

7. These by-laws may be amended by a two-thirds vote of the members present at any regular meeting.

CONSTITUTION OF THE NORTH CENTRAL BRANCH OF THE AMERICAN SOCIETY OF AGRONOMY

ARTICLE I

1. *Name:* The name of this organization shall be the North Central Branch of the American Society of Agronomy.

2. *Area:* It is understood that the North Central Branch includes the states of North Dakota, South Dakota, Minnesota, Iowa, Nebraska, Kansas, Missouri, Illinois, Wisconsin, Indiana, Michigan, Ohio, and the adjacent provinces in Canada.

ARTICLE II

1. *Objectives:* The objectives of this Association shall be: *(1)* the increase and dissemination of Agronomic knowledge, and *(2)* closer acquaintanceship among agronomists within the area.

ARTICLE III

1. *Membership:* Membership may be active or associate.

2. *Active membership* shall depend upon active membership in the American Society of Agronomy, residence within the Branch area, and affiliation with the Branch.

3. *Associate membership* shall depend upon residence within the Branch area, associate membership in the National Society and affiliation with the Branch.

4. *Associate members* may serve on Branch committees and vote on matters pertaining only to the Branch but shall not have the right to hold office in the Branch or vote on matters pertaining to the national organization.

ARTICLE IV

1. *Regular Officers of the Branch:* The regular officers of the Branch shall consist of a chairman, a vice chairman, and a secretary-treasurer. The head of the Department of Agronomy of the host institution for the next annual meeting shall be the Branch chairman and the head of the Department of Agronomy of the host institution for the next following annual meeting shall be the vice chairman. Their respective tenures of office shall expire with the close of the annual meeting. In event of institutions with separate Soils and Crops Departments, there shall be co-chairmen and co-vice chairmen. The secretary-treasurer shall be elected at the annual meeting for a period of one year but may be re-elected. The duties of the officers shall be those usually pertaining to their respective offices.

2. *Representatives of the Branch on Board of Directors of American Society of Agronomy:* The Branch shall be represented on the board of directors of the American Society of Agronomy by a director and an alternate director. Such director and alternate director shall be elected at the annual meeting in even years, the terms to begin at the end of the next annual meeting of the National Society and to be for a period of approximately two years. The director and alternate director shall take office at the end of the next annual meeting of the National Society and continue for approximately two years. Representation of the Branch shall be alternated between the Soils and Crops Divisions.

3. *Suggested Nominees of the Branch for Consideration of the Nominating Committee of the American Society of Agronomy for Vice President of the American Society of Agronomy.* At each annual meeting the Branch will recommend not more than two persons to the nominating committee of the American Society of Agronomy for vice president of that organization. The persons so recommended need not be members of the Branch, but in even years the selection shall be from the Crops Divisions and in odd years from the Soils Divisions.

4. *The Executive Board:* There shall be an executive board consisting of the chairman or co-chairmen, the vice chairman or co-vice chairmen, the secretary-treasurer, and two representatives of the Branch serving as director and alternate director of the American Society of Agronomy. The Executive Board shall handle all business of the Branch arising between annual meetings and all other matters delegated to it by the membership.

5. *Chairman of the Annual Meeting:* The chairman or one of the co-chairmen of the Branch shall be chairman of the annual meeting. The chairman or co-chairman shall have full responsibility for the program and other features of the meeting subject only to expressed direction of the executive board or the membership at previous meetings.

ARTICLE V

Nominations and Elections: At least two months before the annual meeting the Chairman shall appoint a nominating committee. Before the close of the first day of the annual meeting this committee shall list with the secretary-treasurer a slate of at least two nominees for the office of secretary-treasurer and in even years a director and an alternate director. This slate shall be presented at the business meeting at which time additional nominations may be called for. The election shall be by written ballot. In event of more than two candidates for any office the candidate receiving the greatest number of votes shall be declared elected. Nominees of the Branch for national officers shall be included in this ballot.

ARTICLE VI

1. *Time and Place of Meeting:* At least one meeting of the Branch shall be held each year. Unless otherwise determined by the membership or the Executive Board this meeting shall be a summer meeting held at some Agricultural College or Experiment Station.

2. The program shall include observation and study of research, teaching, and extension work, techniques of doing same, and such other activities as may promote the interests of the Branch.

3. The annual business meeting shall be held at such time within the general meeting as the Chairman may determine.

4. The place of meeting from year to year shall in so far as practicable be determined by vote of the members from invitations of various institutions. Otherwise selection of meeting location shall be by the Executive Board.

ARTICLE VII

1. *Dues and Fees:* The amount of dues shall be determined from time to time by the Executive Board subject to such limitations as may be set by the Branch. Graduate and undergraduate students shall be exempt from payment of dues.

2. A registration fee of such amount as the host institution with the approval of the Executive Board may determine may be charged. From this fund the host institution may make necessary expenditures. Any unexpended surplus shall be turned over to the secretary-treasurer as property of the Branch.

3. Funds of the Branch may be used in such manner as the membership or Executive Board may determine.

ARTICLE VIII

Amendments: This Constitution may be amended at any regular meeting by a three-fifths vote of those present and voting provided previous notice of such proposed amendment has been given at the previous regular meeting or by mail by the secretary one month or more prior to the meeting at which action is to be taken. Amendments proposed by mail must have the approval of at least three members of the Executive Board.

CONSTITUTION AND BYLAWS OF THE SOUTHERN BRANCH OF THE AMERICAN SOCIETY OF AGRONOMY AND AGRONOMY SECTION OF ASSOCIATION OF SOUTHERN AGRICULTURAL WORKERS

ARTICLE I

Name: The name of this Association shall be The Southern Branch of the A.S.A. and Agronomy Section of A.S.A.W.

ARTICLE II

Objectives: The objectives of this Association shall be to further the increase and dissemination of agronomic knowledge and to promote closer acquaintance among agronomists within the area and a greater knowledge and consideration of their work.

ARTICLE III

Memberships: There shall be two kinds of membership, active and associate. Active members shall be the active members of the

American Society of Agronomy who reside in the area and who pay the prescribed Branch dues. Associate members shall have all privileges outlined in the Constitution of the American Society of Agronomy.

ARTICLE IV

Officers: Officers shall consist of a President, Chairman (Soils) and Chairman (Crops), and a Secretary-Treasurer. A Secretary-Treasurer shall be elected each year; alternately he shall be chosen as a soils or crops specialist and shall serve as Chairman of either Soils or Crops for two years and then advance to the Presidency.

One Director and One Alternate shall represent the Branch in the Board of Directors of the American Society of Agronomy. The Branch President shall serve as Director and the Branch Officer next in line to become President shall serve as alternate.

Executive Committee: The Executive Committee shall consist of the four officers of the Branch, and shall act upon all matters arising between annual meetings of the Branch.

ARTICLE V

Nomination and Election of Officers: A nominating committee composed of two crops and two soils members shall nominate one or more active members of the Branch for the following offices: *(1)* Secretary-Treasurer, *(2)* Any other office which may be vacant; *(3)* Vice-President of the American Society of Agronomy.

ARTICLE VI

Meetings: Meetings shall be at the same place and during the meetings of the Association of Southern Agricultural Workers and at any special summer tours that may be arranged by approval of the Executive Committee.

ARTICLE VII

Amendments to Constitution: This Constitution may be amended by a three-fifths vote of the active and associate members present at any annual meetings, provided announcement of the proposed amendment has been given at least thirty days prior to such meetings. The Executive Committee may propose amendments at any time between meetings and the same shall be approved or rejected by a three-fifths vote of the members who mail their ballots within thirty days after notice of the proposed amendment was sent them.

BY-LAWS

(1) *(a)* The annual meeting shall be held within the period of the annual meeting of the Association of Southern Agricultural Workers and at the same place. If the A.S.A.W. should fail to hold an annual meeting, the Executive Committee of the Branch shall determine the time and place of the annual meeting.

(b) A summer meeting of the Branch may be held upon the invitation of an Agricultural College or Experiment Station, for the purpose of observing work in progress and of studying and discussing programs and techniques. The responsibility for the program and for arrangements for such summer meetings shall rest with the head of the "Host Department" with such assistance from the regular officers as he may choose to invite.

(2) Funds of the Branch shall be used in support of Branch activities in such manner as the Executive Committee or membership may determine.

(3) These By-Laws may be amended by a three-fifths vote of the members present at any regular meeting.

CONSTITUTION OF THE WESTERN BRANCH OF THE AMERICAN SOCIETY OF AGRONOMY

WHEREAS, the Western Agronomic Workers, known since 1924 as the Western Section of the American Society of Agronomy was organized at a conference held by a group of western agronomists in 1916, and

WHEREAS, the Western Society of Soil Science was organized at a symposium attended by a group of western soil scientists in 1921, and

WHEREAS, these two organizations, each with a long history of successful, independent operation form the logical basis for a Western Branch of the American Society of Agronomy, be it

Resolved, that in order to conform with the By-laws of the American Society of Agronomy and the Soil Science Society of America, especially in regard to the responsibilities of the professional groups known as the Crop Science and Soil Science Divisions, those responsibilities of the Western Branch shall be regulated by the following articles of the Constitution:

ARTICLE I

Name: The name of this organization shall be the Western Branch of the American Society of Agronomy.

ARTICLE II

Objectives: The objectives of the Western Branch shall be to promote and foster the aims and objectives of the American Society of Agronomy in the Western Region of the United States and the western provinces of Canada.

ARTICLE III

Composition: The Western Branch shall be composed of Crop Science and Soil Science Divisions. The Crop Science Divisions shall be represented by the organization first known as the Western Agronomic Workers and later named the Western Section of the American Society of Agronomy. The Soil Science Divisions shall be represented by the Western Society of Soil Science which is the Western Branch of the Soil Science Society of America.

ARTICLE IV

OFFICERS

Section 1: The officers of the Western Branch shall be a President, a Vice-President, and a Secretary-Treasurer. In even-numbered years these positions shall be filled by the officers of the Crop Science Divisions and in odd-numbered years by the officers of the Soil Science Divisions.

Section 2: The duties of the President, Vice-President and Secretary-Treasurer shall be those usually pertaining to the offices held or as prescribed by the by-laws of the Crop Science and Soil Science Divisions. The President as the Chairman of the Board of Directors shall represent the American Society of Agronomy for the Western Branch and shall arrange programs and preside at any joint sessions of the Crop Science and Soil Science Divisions that may be arranged.

Section 3: The Board of Directors shall consist of the President, the most recent past President, and the Secretary-Treasurer of the Branch and the Presidents of the Crop Science and Soil Science Divisions. The President shall serve as Chairman.

Section 4: The Board of Directors is the legal representative of the Western Branch and shall act in that capacity.

Section 5: The Board of Directors shall appoint one director and one alternate to represent the Western Branch on the Board of Directors of the American Society of Agronomy. The appointees who shall serve as director and alternate for the first term of two years shall be the President of the Crop Science Divisions and Vice-President of the Soil Science Divisions, respectively. They shall be succeeded by the President of the Soil Science Divisions as director and the Vice-President of the Crop Science Divisions as alternate to serve for the second term of two years. Subsequent terms shall be rotated in the same order.

Section 6: The Vice-Presidential nominee of the American Society of Agronomy from the Western Branch shall be nominated by its Crop Science Divisions in even-numbered years, and by its Soil Science Divisions in odd-numbered years.

ARTICLE V

AMENDMENTS

Section 1: Any twenty (20) or more active members of the Western Branch, may initiate a proposed amendment to this constitution.

Section 2: The Board of Directors shall submit the proposed amendments to all active members of the Western Branch at least thirty (30) days before voting. The adoption of a proposed amendment shall require a majority vote of those present at the annual meetings of the Crop Science Divisions and the Soil Science Divisions.

BYLAWS OF THE WESTERN SOCIETY OF SOIL SCIENCE

Adopted June 23, 1954, Pullman, Washington

A. NAME

The name of this society shall be the Western Society of Soil Science. The Society shall serve as the Western Branch of the Soil

Science Society of America and as the Soil Science Divisions of the Western Branch of the American Society of Agronomy.

B. OBJECTIVES

1. The general objective of the Society shall be to promote research, teaching, and extension in soil science and plant nutrition in the geographical area of the Western Region of the United States and the western provinces of Canada, and to cooperate with other societies and organizations concerned with soil and plant nutrition problems in this area.

C. MEMBERSHIP

1. Any person or organization interested in the general objective of the Society shall be eligible for membership.
2. Active members shall be those who have paid their annual dues to the Secretary-Treasurer. The membership year shall extend from January 1 to December 31. Active members need not be members of the Soil Science Society of America, although such membership is encouraged.

D. OFFICERS

1. The officers of the Society shall be a President, a Vice-President who is the President-Elect, and a Secretary-Treasurer. The officers must be members of the Soil Science Society of America.
2. The officers shall serve for approximately one year from the close of the annual meeting of the Society to the close of the next annual meeting. The Vice-President shall automatically succeed to the Presidency at the close of the annual meeting, or at the death or resignation of the President. The Secretary-Treasurer shall serve as the representative of the Society to the Pacific Division of the American Association for the Advancement of Science.
3. The President shall have general responsibility for the affairs of the Society, shall arrange the program for the general sessions at Society meetings, shall preside at the general meetings and at the annual business meeting, and shall have charge of the election of officers.
4. The Vice-President with the advice of the President and the assistance of the Secretary-Treasurer and others the President may appoint to assist in local arrangements shall have charge of the planning and organization of the program for the technical sessions of the annual meeting.
5. The other duties of the President, Vice-President, and Secretary-Treasurer shall be those usually pertaining to the offices held.
6. The Vice-President and Secretary-Treasurer shall be elected by ballot from a slate of candidates supplied by the Nominating Committee.
7. In odd-numbered years, at the annual business meeting the members of the Society shall elect a candidate for Vice-President of the American Society of Agronomy to propose to the nominating committee of the latter society. This candidate shall be selected on the basis of qualifications for the office and without reference to residence.

E. EXECUTIVE COMMITTEE

1. The Executive Committee shall consist of the President, the Vice-President, the Secretary-Treasurer, and the two most recent past Presidents. The President shall serve as Chairman.
2. The Executive Committee is the legal representative of the Society and as such, it shall have, hold and administer all funds and property of the Society in conformity with the By-Laws. Vacancies in offices occurring between annual meetings shall be filled by the Executive Committee until the next annual meeting at which time the position shall be filled in accordance with the By-Laws. The Executive Committee shall also have power to act on all other matters that arise between annual meetings.

F. OTHER COMMITTEES

1. The Nominating Committee shall consist of the most recent past President serving as Chairman and four additional active members appointed by the President. One or more eligible members whose willingness to serve has been ascertained shall make up the slate of candidates for each office to be filled.
2. The President shall appoint such other committees and representatives as are necessary to conduct the affairs of the Society.

G. MEETINGS

1. There shall normally be an annual meeting of the Society for presentation of papers, interchange of ideas, and transaction of business.
2. The time and place of the annual meeting shall be determined by the Executive Committee with concurrence of the members at the annual business meeting. The time and place of the meeting shall normally be the same as for the Pacific Division of the American Association for the Advancement of Science.
3. At any meeting of the Society, five (5) percent of the active membership shall constitute a quorum for the transaction of business.

H. DUES

1. The annual dues for membership shall be proposed by the Executive Committee and voted on by the active members at the annual business meeting.
2. Members in arrears on Sept. 1 for dues for the 2 previous calendar years shall be dropped from the roll of the Secretary-Treasurer until reinstated on payment of dues.
3. A registration fee may be levied for local arrangements with the approval of the Executive Committee to meet unusual obligations incurred for the annual meeting.

I. AMENDMENTS

1. Any twenty (20) or more active members of the Society may initiate a proposed amendment to the By-Laws. Proposed amendments shall be submitted to the Society by the Executive Committee with recommendations at the next annual meeting, or by mail to all active members prior to the annual meeting.
2. The Executive Committee may propose amendments to these By-Laws at any time by mail ballot or at the annual meeting.
3. The Executive Committee shall submit proposed amendments to all active members of the Society at least 30 days before they are voted on.
4. The adoption of a proposed amendment shall require a majority vote of all the active members present at the annual meeting, or of all ballots returned within (30) days following the date of original mailing.

BYLAWS OF THE WESTERN SOCIETY OF CROP SCIENCE

1. NAME

The name of this organization shall be the Western Society of Crop Science which shall represent the Crop Science Divisions of the Western Branch of the American Society of Agronomy.

2. OBJECTIVES

The objectives of the Western Society of Crop Science shall be to promote and foster the aims of the American Society of Agronomy in the western states and in the western provinces of Canada.

3. MEMBERSHIP

Section 1: The membership shall consist of individuals and organizations interested in the objectives of the Western Society of Crop Science. Members shall be assessed dues as provided in By-law 7, and shall receive ballots, notification of meetings, programs, and abstracts.

Section 2: Active members are those who have paid their annual dues to the Secretary-Treasurer. It shall not be necessary for active members to be members of the American Society of Agronomy.

4. OFFICERS

Section 1: The officers of the Western Society of Crop Science shall be a President, a Vice-President who is the President-elect, and a Secretary-Treasurer who shall be members of the American Society of Agronomy.

Section 2: The Vice-President shall be elected by mail ballot at the time of the announcement of the next annual meeting of the Western Society of Crop Science. The nominating committee of at least three members well distributed geographically and appointed by the President shall nominate at least two members for the position and obtain their consent to be entered on the ballot. Nominations shall be made with reference to the residence of the nominees within the area of the Western Branch and on qualification for office.

Section 3: The President shall serve for approximately one year as hereinafter provided. The Vice-President, or President-elect, shall serve for approximately one year, as hereinafter provided, after which he shall automatically succeed to the presidency. The

terms of office for the President and Vice-President shall expire at the close of the last session of the annual meeting for that year.

Section 4: The Secretary-Treasurer shall be chosen by the Head of the Agronomy Department of the host institution for the next annual meeting. Selection of the Secretary-Treasurer shall be made with reference to the residence and qualification for office. The term of office shall be for one year and expire at the close of the last meeting for that year. The name of the Secretary-Treasurer shall be presented to the President at the time of the invitation for the next annual meeting.

Section 5: The Executive Committee shall consist of the President, the Vice-President, Secretary-Treasurer, and the most recent Past President.

Section 6: The Executive Committee is the legal representative of the Western Society of Crop Science. As such it shall have, hold, and administer all funds and property of the Western Society of Crop Science in conformity with the By-laws.

Section 7: The duties of the President, Vice-President, and Secretary-Treasurer shall be those which usually pertain to the offices held, or as prescribed by the By-laws.

Section 8: Vacancies in offices shall be filled by the Executive Committee until the next annual meeting, at which time the positions may be filled by election as described above.

Section 9: The Vice-Presidential nominee of the American Society of Agronomy from the Western Branch shall be nominated as provided for in the Constitution of the Western Branch: Article IV, Section 6.

Section 10: The director and alternate to represent the Western Branch on the Board of Directors of the American Society of Agronomy shall be appointed as provided for in the Constitution of the Western Branch: Article IV, Section 5.

5. MEETINGS

Section 1: There shall normally be an annual meeting of the Western Society of Crop Science for the presentation of papers, the interchange of ideas and information, and for the transaction of business. Any year that the national meeting of the American Society of Agronomy is held in the geographical area composing the Western Branch, the annual meeting of the Western Society of Crop Science of the Western Branch shall consist only of a business meeting held conjunction with the national meeting.

Section 2: The location of the annual meetings shall follow the revolving pattern previously established of meeting whenever possible at the Experiment Station of the institutions in the western states and in the western provinces of Canada.

Section 3: Prior to the annual meeting the President shall secure an invitation and a nomination of a Secretary-Treasurer from the host institution for the next annual meeting. This invitation and nomination of the Secretary-Treasurer shall be placed before the membership at the annual business meeting for approval.

Section 4: The dates of the annual meeting shall be determined by the Executive Committee upon recommendation from the host institution.

6. COMMITTEES

Section 1: The standing committees of the Western Society of Crop Science shall be appointed by the President, unless otherwise specified.

Section 2: The program committee for the annual meeting shall consist of the Vice-President as chairman, and the Secretary-Treasurer in charge of local arrangements. On recommendation of the Vice-President, the President may name additional members to the program committee.

Section 3: A local arrangements committee shall be chosen by the Secretary-Treasurer. This committee shall be in charge of the local arrangements—such as housing, meeting places, field trips, and other planned activities for the annual meeting.

Section 4: Special committees and representatives of the Western Society of Crop Science to other organizations may be chosen by the President as deemed desirable.

7. DUES

Section 1: The annual membership dues of the Western Society of Crop Science shall be proposed by the Executive Committee and passed upon by the membership at the annual meeting. They will be paid to the Secretary-Treasurer when ballots are returned prior to each annual meeting. The funds received from such dues shall be used to support the activities of the Western Society of Crop Science.

Section 2: A registration fee may be levied by the local arrangements committee to meet any obligations incurred for the annual meeting.

8. AMENDMENTS

Section 1: Any 20 or more active members of the Western Society of Crop Science may initiate a proposed amendment to these bylaws. This amendment shall be considered by the Executive Committee and submitted to the Western Society of Crop Science with recommendations either by mail ballot or at the next annual meeting, as they deem desirable.

Section 2: The adoption of a proposed amendment shall require a majority of all ballots returned within a specified time after the date of the original mailing.

Book Reviews

SOIL FERTILITY

By C. E. Millar. New York, John Wiley & Sons, Inc. 436 pp. 6 by 9¼. illus. 1955. $6.75.

From a long and distinguished career in the soil science department of Michigan State University, the author draws on his wide knowledge to give unusually wide coverage to the subject of soil fertility in this book. From the "plant's point of view," soil chemistry, physics and microbiology are discussed along with their relationships to plant physiology. Each of the major nutrients and the more important trace elements are discussed with respect to their supply in the soil, sources and amounts of additions, losses from the soils, their functions in plant growth, and deficiency symptoms.

Aspects considered in separate chapters are soil solution and nutrient absorption by plants, colloids and soil productivity, pH and liming, organic matter, soil deficiencies and methods for determining nutrient needs of crops, activities of soil organisms, use of green manures, crop residues, and composts, contributions of commercial fertilizers to soil productivity, and rotations and cropping systems in different sections of the United States. Problems of saline soils and irrigation are not overlooked. Of especial value to the student is the attention given to field trials, particularly the classical experiments.

GRASSLAND FARMING

By George H. Serviss and Gilbert H. Ahlgren. New York, John Wiley & Sons, Inc.; London, Chapman & Hall. 1955. 146 pp. $2.96.

The principles and practices of grassland farming are now quite firmly implanted and fostered throughout the segment of agriculture devoted to animal production. The clearly written book deals with the several active farm operations in grassland farming. It is written primarily for high school students, but the authors also keep the actual farm operator in mind. There are 12 chapters on the following topics: growing grassland crops, using forage in livestock feeding, growing forage for profit, selecting legumes, selecting grasses, choosing seed and establishing seedlings, adding lime and fertilizer, managing pastures, managing hay crops, preserving forage, conservation cropping, and equipping the grassland farm.

The contents of the chapter on using forage in livestock feeding indicates the thorough treatment characteristic of the entire book; this chapter discusses feed sources, price relationships, feeding problems of dairy cattle, beef cattle, sheep, lambs, hogs, and poultry, forage capacity of livestock, forage composition as to proteins, energy, minerals, vitamins and moisture, and total digestible nutrients. Although the selected reading, questions and suggested activities listed after each chapter are primarily for the teacher and student, attention to them by the general farm reader will help find answers to many every-day problems in grassland farming.

CHEMISTRY OF THE SOIL

Edited by Firman E. Bear. New York, Reinhold Publishing Corp. 1955. 373 pp. $8.75.

Thirteen soil scientists have contributed to this book which is Monograph 126 of the American Chemical Society. They have collaborated on one of the most complete, if not the most complete, works on the subject of soil chemistry thus far published. There are 10 chapters on soil development, chemical composition, colloid chemistry, cation and anion exchange, organic matter, nutrient fixation, oxidation-reduction, soil reaction, trace elements, and plant nutrition. Contributors are Isaac Barshad, Kirk Lawton, Stephen G. Toth, L. T. Kardos, F. G. Merkle, D. W. Thorne, Lloyd F. Seatz, Adolf Mehlich, Mack Drake, Lambert Wiklander (Sweden), George K. Fraser and Robert L. Mitchell (both of Scotland), and Arthur L. Prince. Each chapter is well-documented with literature citations, and an excellent appendix is devoted to methods of soil analysis. Soil fertility specialists will not want to keep this title from their personal libraries.

GRAIN CROPS

By Harold K. Wilson. McGraw, Hill Book Co., New York. 396 pages, illus. 1955. ($6.50).

This is a revision of the first book released in 1948. This new edition gives the more recent advances in the field. Included is an up-to-date discussion of the control of plant diseases, insects and weeds, and new information on soils and soil fertility. Illustrations have been chosen to show the present status of grain crops and the references have been made current.

This text is organized for use in an elementary course in grain crops. However, it would be valuable to the layman needing practical information on grain production.

The author, a man of wide experience in Agronomy, has done an excellent job in presenting a logical arrangement of material dealing first with broad fundamentals and principals, followed by specific treatment of each grain crop. The general chapters, 1 to 9 and 23 and 24 inclusive are particularly strong; clearly written, concise, readable.

The introductory chapters on the grain crops and their environment are excellent; and include plant classification, distribution, rotations, soils, culture, weeds, diseases, and insect pests. After the introductory chapters, there are 13 chapters on the more important specific crops. These chapters are only moderately strong because the treatment of specific crops is brief. The last two general chapters deal with marketing and marketing problems and the fundamentals of crop improvement.

Illustrations are well chosen and clear, with definite legends. Each chapter has a number of review questions to stimulate thinking on the part of the student.

For anyone who desires a good text for grain crops or a ready reference on the culture of grain crops, this second edition, like the first, will adequately fulfill his needs.—Darrel S. Metcalfe.

THE GENUS NICOTIANA. ORIGINS, RELATIONSHIPS AND EVOLUTION OF ITS SPECIES IN THE LIGHT OF THEIR DISTRIBUTION, MORPHOLOGY AND CYTOGENETICS

By Thomas Harper Goodspeed. Chronica Botanica; New York, Stechert–Hafner. xxii + 536 pages, 118 plates and illus. 1954. $12.50.

This book is a monographic study made over a period of nearly 50 years of the 60 species of Nicotiana. It is unique in that the author has made many observations on living plants of 56 of the species rather than on herbarium specimens. He has also had access to all herbarium materials. Parts I-V deal with their morphology, cytology, geographic distribution, and phylogeny. The chromosome behavior of over 200 F_1 interspecific hybrids is analyzed. Part VI, done in collaboration with H-M. Wheeler and P. C. Hutchison, treats of the taxonomy of each species. Each is illustrated with line drawings. There are keys to the subgenera, sections, and species.

The mass of data assembled in this book makes it especially valuable to the geneticist, agronomist, and plant pathologist. Since some species of Nicotiana are resistant to specific diseases, its concepts are of practical importance for use to improve quality and resistance to diseases in cultivated kinds of tobacco.—F. A. Wolf.

Agronomic Affairs

MEETINGS

July 25–28, Northeast Branch, American Society of Agronomy, Pennsylvania State University.

Aug. 1–6, 3rd International Congress of Biochemistry, Brussells, Belgium.

Aug. 10–11, 24th Annual Golf Course Superintendents' Field Day, Rhode Island Agricultural Experiment Station, Kingston, R. I.

Aug. 15–19, American Society of Agronomy and Soil Science Society of America, University of California College of Agriculture, Davis.

Aug. 29–Sept. 6, International Horticultural Congress, Scheveningen, Holland.

Sept. 7–9, American Society for Horticultural Science, Michigan State University, East Lansing, Mich.

PROGRAM FOR ANNUAL MEETING NEARS COMPLETION

Two hundred eighty-two technical papers are scheduled for presentation at the annual meeting of the American Society of Agronomy Aug. 15–19 at the University of California College of Agriculture, Davis, Calif.

Of the total, 166 will be read at the various divisional meetings of the Soil Science Society, 110 at meetings of the Crop Science Divisions, and the Agronomic Education Division, and 6 at a special meeting on "Land Use and Management" arranged by U. S. Defense Department agronomists.

At the general meeting of the ASA at 1:30 p.m. Monday, Aug. 15, H. R. WELLMAN, vice president for Agricultural Science of the University of California, will present an invitational paper on "Public Supported Research in Agriculture." The usual committee and other officer reports will be presented at this meeting.

The Soil Science Society and the Crop Science Divisions will hold their separate general meetings on Tuesday evening, Aug. 16. The Agronomic Education Division will hold its business meeting Tuesday morning. Business meetings of the Western Society of Soil Science and Western Society of Crop Science are scheduled prior to the national meetings on Tuesday.

SPECIAL MEETINGS

Special meetings scheduled throughout the week are as follows:

Western Barbecue, Monday evening, Aug. 15, sponsored by the California Seed Association; Annual Banquet of the American Society of Agronomy, Wednesday evening, Aug. 17; "Hawaiian luau", Thursday evening, Aug. 18.

The National Joint Committee on Fertilizer Application will hold its luncheon meeting on Monday, and the Extension Workers Annual Breakfast will be held on Wednesday, Aug. 17.

Activities for women include a trip to the San Francisco Bay area on Aug. 16, trip to Sacramento, Aug. 17, and a ladies luncheon on Aug. 18.

Several field trips are scheduled before, during, and after the meetings in Davis. Displaying the great diversity of California's agriculture, these are as follows:

Friday, Aug. 12. Two-day trip sponsored by Certified Alfalfa Seed Council to view alfalfa seed-producing in the San Joaquin Valley.

Saturday, Aug. 13. One-day trip to observe alkali soils and reclamation experiments in Fresno, Kings, and Tulare counties.

Tuesday, Aug. 16 and Wednesday, Aug. 17. Agronomy field trips to experimental plots north of Davis.

Friday, Aug. 19. Soils field trip to observe soils and land use in the Sacramento Valley; Sierra Nevada field trip, all day trip to observe hilly and mountainous areas; Hopland Field Station, all-day trip to observe range management and wildlife; tour of the Berkeley campus of the University of California.

Saturday, Aug. 20. An all-day trip to the Coast Range Mountains and Clear Lake. A 4-day extension of this trip is planned into northern California and Oregon.

The 2-day alfalfa field trip will be repeated Aug. 19–21.

IRRIGATION SHOW

The University of California irrigation department has arranged an irrigation show Wednesday and Thursday, Aug. 17 and 18, at 8:30 a.m. in the hydraulic laboratory. All types of irrigation equipment will be on display, including and leveling and grading machinery, siphons, valves, spiles, etc., sprinklers, fertilizer injection equipment, pipes and tile, and moisture measuring and control devices.

RECORD ATTENDANCE AT NORTH CENTRAL BRANCH MEETING

A new record attendance of 466 crop and soil scientists registered at the 1955 meeting of the North Central Branch of the American Society of Agronomy held June 26–29 at Iowa State College, Ames.

Officers for the coming year are J. B. PETERSON, Purdue University, chairman; T. E. STOA, North Dakota Agricultural College, vice chairman; and FLOYD SMITH, Kansas State College, (re-elected) secretary-treasurer.

The 1956 meeting will be held at Purdue University, Lafayette, Ind. North Dakota Agricultural College will be host for the 1957 meeting.

ALFALFA SEED COUNCIL HONORS H. M. TYSDAL

H. M. TYSDAL, left, is shown accepting a plaque at ceremonies in Washington, D.C., May 13 honoring him for his contributions to the development of Ranger alfalfa. Shown with Dr. Tysdal from the left are Mrs. TYSDAL, WILL H. MYERS, chairman of the department of agronomy and plant genetics, University of Minnesota, and LLOYD ARNOLD, chairman of the Certified Alfalfa Seed Council. The plaque was presented at a dinner in Washington. Speakers in addition to Dr. Myers, who related the work of Dr. Tysdal, were Secretary of Agriculture EZRA BENSON; B. T. SHAW, ARS administrator, THEODORE S. GOLD, assistant secretary of agriculture; DAVE BEARD, Head of Forage and Range Section, ARS; HOWARD SPRAGUE, chairman, agronomy department, Pennsylvania State University; T. E. ODLAND, chairman, agronomy department, Rhode Island University; KELLER E. BEESON, Purdue University; C. P. WILSIE, Iowa State College; FRANK PARSONS, University of California; RALPH D. MERCER, Montana State College, and JIM ROE, *Successful Farming*, Des Moines, Iowa. The inscription on the plaque reads as follows:

HEWITT M. TYSDAL

For inspiration and leadership in alfalfa research and outstanding accomplishments contributing to the development and release, seed production and extensive use of

RANGER ALFALFA

the first wilt-resistant variety of which over 100,000,000 pounds of certified seed had been planted by American farmers on this date: Friday, May 13, 1955.

MEMBERS INVITED TO TOUR WASHINGTON STATIONS

Agronomists in the State of Washington extend a cordial invitation to Society members to visit Pullman and other Washington Experiment Stations on their trips to and from the Society's annual meeting at Davis, Calif., says B. R. BERTRAMSON, chairman of the Washington State College agronomy department.

No formal field tours are planned, but visitors from other states are invited to visit Washington State facilities. While many of the crops in Eastern Washington will have been harvested by that time, there will be crops in the field at the following outlying stations:

Irrigation Experiment Station, Prosser; Dryland Experiment Station, Lind: Southwestern Experiment Station, Vancouver; Western Washington Experiment Station, Puyallup; and Northwestern Washington Experiment Station, Mt. Vernon. Soils work can also be seen at the tree Fruit Station, Wenatchee.

Crop and soil scientists at Oregon State College, Corvallis, extended a similar invitation earlier this year.

SEVERAL RECEIVE USDA SERVICE AWARDS

Several members of the American Society of Agronomy and the Soil Science Society of America were among the many USDA personnel who received the 1955 service awards of the department. Following is a list of members together with excerpts from the award citations:

BYRON T. SHAW, ARS, Washington, D. C.: For his vision in recognizing the nation's agricultural research requirements, and for demonstrating exceptional leadership in planning and executing outstanding research and related scientific programs to derive optimum benefits therefrom.

GLENN W. BURTON, ARS, Tifton, Ga.: For developing new techniques and procedures involving fundamental studies in breeding behavior and interspecific hybridization which has been responsible for developing five Bermudagrass varieties.

HARLEY A. DANIEL, ARS, Guthrie, Okla.: For his participation in the development of a system for judging land and promoting soil conservation practices which contributed greatly to the improvement of agriculture and rural life in the Red Plains area of Oklahoma.

FRANK LESLIE DULEY, ARS, Lincoln, Nebr.: For his participation in the origination and development of the stubble mulch system of farming; sustained crop production; and conservation of soil and water resources in dry-farming areas of the West.

JAMES R. MEYER, ARS, Stoneville, Miss.: For notable contributions to cotton genetics and breeding research by developing new cytogenetic techniques and transferrance of new characters from wild to cultivated species.

GEORGE A. ROGLER, ARS, Mandan, N. Dak.: For developing several improved grass varieties, particularly the crested wheatgrass, Nordan, which has been a major contribution to improved agriculture of the Northern Great Plains.

FRANK G. VIETS, JR., ARS, Fort Collins, Colo.: For assessing soil fertility needs of irrigated lands in the Columbia River Basin, including diagnosing and describing zinc deficiency symptoms, determining critical zinc levels, and devising economical methods of correcting deficiencies.

N. C. BRADY HEADS CORNELL DEPARTMENT

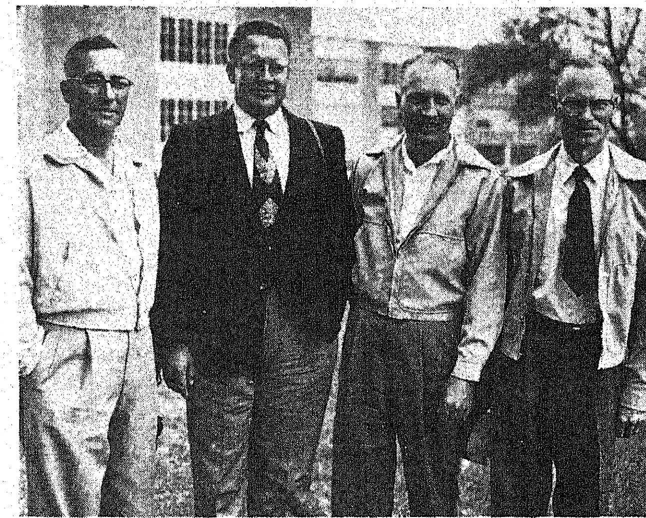
N. C. BRADY, professor of soil science at Cornell University, Ithaca, N.Y., was appointed head of the agronomy department at Cornell on July 1. He succeeds RICHARD BRADFIELD who had been department head since 1947.

DR. BRADFIELD, at present on leave as regional director for the Rockefeller Foundation Far East Agricultural Program, will continue as professor of soil technology.

N. C. Brady

Dr. Brady was born and reared on a farm near Manassa, Colo. He was graduated from Brigham Young University, Provo, Utah, and received his Ph.D. degree from the University of North Carolina. He has been at Cornell University for the past 8 years. In 1953–54, Dr. Brady spent 18 months at the University of the Philippines helping to train agricultural leaders and to develop cooperative research work between the university and other agencies. He is past chairman of the resident teaching section of the Agronomic Education Division, American Society of Agronomy.

OFFICERS OF WESTERN GRASS BREEDERS CONFERENCE



New officers of the Western Grass Breeders Conference, pictured above, are, from left, WESLEY KELLER, Utah State Agricultural College, secretary; R. C. PICKETT, Kansas State College, vice-president; J. K. PATTERSON, Washington State College, president; and R. E. STITT, Montana State College, past president.

The Plains and Inter-mountain states were represented with an official attendance of 48 at the conference June 13 and 14 at Pullman, Wash., and Moscow, Idaho. The conference included paper presentations at the two morning sessions and afternoon field trips to visit forage work at the Washington and Idaho Experiment Stations.

The conference will meet at South Dakota State College in 1956.

NATIONAL PLANT FOOD INSTITUTE IS LAUNCHED

On July 1, the American Plant Food Council and the National Fertilizer Association were consolidated as the National Plant Food Institute. The consolidation was approved by the respective members of the two parent organizations last fall. Executive vice presidents of the Institute are PAUL T. TRUITT, former president of the Plant Food Council, and RUSSELL COLEMAN, former president of the American Fertilizer Assn. W. R. ALLSTETTER is vice-president. Other officers and staff of the Institute were to be elected by the Board of Directors at its first official meeting this month.

Offices of the Institute are at 1700 K Street, NW, Washington 6, D. C.

Official publication of the Institute is the quarterly *Plant Food Review*. It is a consolidation of the *Plant Food Journal* and the *National Fertilizer Review*.

SORBONNE IS SITE OF 1956 SOIL SCIENCE CONGRESS

Meetings of the 6th Congress of the International Society of Soil Science will take place at the Sorbonne in Paris, France, Aug. 20 to Sept. 8, 1956. During the Congress there will be a 1-day excursion into the Paris environs. Several 1-week excursions to run simultaneously are also planned for various areas of France.

Oct. 1 is the deadline for abstracts or papers to be given at the Congress.

M. B. RUSSELL, president of the Soil Science Society of America, is chairman of Commission II (Soil Physics). Abstracts of papers for this commission should be submitted to him at the Agronomy Department, University of Illinois, before that date.

COMMUNICATIONS

ELECTRIC CURRENT MUTATIONS

Since writing you on June 6, I have had an opportunity to look over the work referred to by Mr. SAUCHELLI in his letter of May 20 to you *(Agron. Jour.* 47:287). Although the work is quite extensive in nature, there is really nothing of significance genetically in it. I took the opportunity of having one of our visiting scientists, Dr. R. E. Scossiroli from Pavia, Italy, look over the publication and give me his appraisal of it. He knows the author,

Dr. ALBERTO PIROVANO, who is still living and doing research. Dr. PIROVANO used many sorts of radiations, including X-rays, ultraviolet, electro-magnetic radiations and others, on a number of plant species. He found that he was able to sterilize the pollen by a number of radiations but actually he found no mutations as we see them today. His work certainly is not in a class with Dr. Muller nor even in a class with that of Dr. Mavor, whose work I cited in the talk before the Agronomy Society.

W. R. SINGLETON

Brookhaven National Laboratory
Upton, L. I., N. Y.

NEWS NOTES

GEORGE M. SCHAFER was transferred in May from the SCS Soil Survey staff at the Iowa Agricultural Experiment Station, Ames, to the Ohio State Conservationist's Office at Columbus as a Soil Scientist in Soil Classification and Mapping.

—A—

GEORGE SNEDECOR, professor and former head of the department of statistics at Iowa State College, was one of six Iowa State College faculty members who received Faculty Citations at the annual Alumni Day activities at Ames on June 11.

—A—

JACKSON B. HESTER, JR. of Elkton, Md., who received his B.S. degree in chemistry in June from Massachusetts Institute of Technology, has accepted a position for the summer with duPont's Organic Chemistry Laboratories at Deepwater, N. J., and will pursue graduate studies in chemistry this fall at the University of Wisconsin.

—A—

Purdue University's agronomy department reports the following personnel news:

GEORGE H. ENFIELD, Purdue Extension Agronomist, will join the Federal Extension Service Staff on Aug. 1 as agronomist in soils. He returned to Purdue last December from a Point 4 assignment in Iran and Jordan.

M. O. PENCE, Purdue's veteran Extension Agronomist, partially retired on July 1. He has been a leader in Indiana Extension work for nearly 35 years, and is best known for his leadership in pasture improvement and the 5-acre corn contest.

CHARLES FOY recently joined the Purdue Agronomy Department as Assistant Professor to work on the nutrition and physiology of forage plants. Foy is a graduate of the University of Tennessee and did his graduate work at Purdue.

DONALD L. MCCUNE is now land management specialist at Purdue, and will conduct field and laboratory research on water loss and erosion. He is a graduate of Ohio State University, and is completing advanced work at Purdue.

G. G. WILLIAMS has accepted a position as Manager of Irrigation Research and Development with Olin-Mathieson Chemical Corp., Little Rock, Ark. Dr. Williams has been a leader in irrigation research at Purdue for the past 5 years.

—A—

FRANK ROBINSON, graduate of Rutgers University, has returned to Purdue from the armed services. He is continuing his work toward a Ph.D. in soil physics under HELMUT KOHNKE.

—A—

DARNELL M. WHITT is the new research liaison representative in the corn belt states for the USDA Soil Conservation Service and the Soil and Water Conservation Research Branch of ARS. He succeeds HOWARD W. REAM, who resigned to accept a position with FOA in the Philippine Islands. Dr. Whitt's office will remain temporarily at the University of Missouri.

—A—

JESSE COLLIER, who recently completed work for the Ph.D. degree at Rutgers University, New Brunswick, N. J., has returned to the Branch Experiment Station at Temple, Tex., where he is engaged in hybrid corn breeding.

—A—

After 2 years service in the U.S. Army Transportation Corps, G. A. MARX has returned to the University of Wisconsin where he is studying for the Ph.D. degree in agronomy. He had been stationed at Fort Lawton, Wash., and was discharged June 3.

—A—

PAUL H. HARVEY has been named William Neal Reynolds Professor of Agriculture at North Carolina State College, Raleigh. Dr. Harvey is a native of Nebraska, and has been at North Carolina State College since 1938. The Reynolds Professorship is the highest honor awarded to faculty members at N.C. State College.

—A—

GUY O. WOODWARD, Wyoming extension irrigation specialist for the past 7 years, resigned July 1 to become education director of the Sprinkler Irrigation Association, Salt Lake City.

—A—

GEORGE S. CRIPPS has been appointed manager of agricultural development in the chemical division of Climax Molybdenum Co.

—A—

DARRELL A. RUSSELL, assistant in soil fertility at the University of Illinois, will leave Urbana Aug. 1 for a new position as assistant soil chemist at the North Louisiana Hill Farm Experiment Station at Homer, La. His new work will involve soil testing, soil testing research, and soil fertility research. He will receive the Ph.D. degree from the University of Illinois in October.

—A—

GEORGE STANFORD has resigned as professor of soils at Iowa State College to accept a permanent position as chief of the soil and fertilizer research branch of the TVA division of agricultural relations. His permanent headquarters will be at Wilson Dam, Ala., where research work will be carried on in cooperation with the fertilizer research group there. Dr. Stanford has been on the Iowa State College faculty since 1950.

CORRECTION

(1) The table of contents on the cover of the June 1955 issue of *Agronomy Journal* incorrectly lists *Helen D. Miller* as co-author of the article, "*Lolium perenne* L. × Tetraploid *Festuca elatior* L. Triploid Hybrids and Colchicine Treatments for Inducing Auto-allohexaploids." *Helen D. Hill* is the co-author.

(2) On page 258 of the June 1955 issue of *Agronomy Journal*, the second line of the second paragraph, substitute *triploid* for *diploid*.

PERSONNEL SERVICE

The Personnel Service column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of $2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a key number which will be carried for five additional insertions unless a discontinue order is received. Items pertaining to soils positions will be inserted one time in the *Soil Science Society of America Proceedings* unless otherwise specified. The following insertions, published in earlier issues, are still available: 2–1, 2–2, 2–3, 4–1, 4–2, 4–3, 6–1.

POSITION WANTED

Soil Scientist, M.S. (Ohio State Univ., 1922), presently employed in the Soil Conservation Service, whose voluntary resignation becomes effective 22 September 1955 COB, desires an assignment in research. The past ten years have been spent in making soil permeability determinations. Other experiences include soil conservation survey mapping, and employment on the Arlington Farm. Write WALTER L. TURNER, JR., 705 N. Main Street, Blacksburg, Virginia. 7–1.

—A—

Soil Fertility, Ph.D. (Univ. of Wis. 1954) presently employed, desires teaching or research position in soils. Four years experience in college teaching. Chemistry, botany, and horticulture background. Veteran, age 31, family. 7–2.

—A—

Soil Chemist—Ph.D. June 1955. Age 26. Minors: physical chemistry, statistics. Expert flame photometrist. Experience in trouble shooting electronic equipment, in techniques of radioactivity measurements, and in use of spectograph for analysis of soil and plant materials. Academic experience includes graduate assistantship and summer teaching at graduate level. Member of usual professional, scientific, and honorary societies. Seeking industrial or academic position. Available immedately. 7–3.

Membership List, American Society of Agronomy, June 30, 1955

ACTIVE MEMBERS

ALABAMA

F. Adams ---- Auburn
G. Allred ---- Auburn
R. Y. Bailey* ---- Auburn
F. E. Boyd ---- Montgomery
J. D. Burns ---- Auburn
F. Campbell ---- Montgomery
J. T. Cope, Jr. ---- Auburn
B. P. Curtis ---- Fairfield
E. D. Donnelly ---- Auburn
L. E. Ensminger ---- Auburn
K. E. Fussell ---- Guntersville
P. B. Gibson ---- Auburn
W. R. Gill ---- Auburn
J. T. Hood ---- Auburn
C. C. King, Jr. ---- Leighton
R. Langford ---- Auburn
J. C. Lowery ---- Auburn
F. S. McCain ---- Auburn
J. A. Naftel ---- Auburn
M. L. Nichols ---- Auburn
R. W. Pearson ---- Auburn
H. T. Rogers ---- Auburn
R. D. Rouse ---- Auburn
G. S. Rowe ---- Huntsville
C. E. Scarsbrook ---- Auburn
C. F. Simmons ---- Auburn
A. L. Smith ---- Auburn
R. C. Smith, Jr. ---- Huntsville
G. Stanford ---- Wilson Dam
D. G. Sturkie ---- Auburn
W. Thomas ---- Normal
M. I. Timonin ---- Spring Hill
H. S. Ward, Jr. ---- Auburn
J. I. Wear ---- Auburn
C. M. Wilson ---- Auburn

ARIZONA

A. C. Anderson ---- Prescott
L. C. Brown ---- Tucson
T. F. Buehrer ---- Tucson
A. B. Caster ---- Phoenix
A. D. Day ---- Tucson
C. C. Ellwood ---- Tucson
W. D. Fisher ---- Tucson
J. E. Fletcher ---- Tucson
R. B. Foster ---- Tucson
W. H. Fuller ---- Tucson
N. W. Gilbert ---- Tempe
J. Hamilton ---- Yuma
K. C. Hamilton ---- Tucson
A. H. Hyer ---- Sacaton
M. N. Langley ---- Yuma
D. F. McAlister ---- Tucson
W. T. McGeorge* ---- Tucson
S. E. McGregor ---- Tucson
R. H. Peebles ---- Sacaton
E. H. Pressley ---- Tucson
G. L. Richardson ---- Tempe
D. D. Rubis ---- Mesa
H. V. Smith ---- Tucson
C. O. Stanberry ---- Yuma
M. J. Sullivan ---- Phoenix
F. E. Todd ---- Tucson
J. P. Trimble ---- Aguila
B. M. Waddle ---- Sacaton
M. H. Wallace ---- Phoenix

ARKANSAS

R. L. Beacher ---- Fayetteville
D. A. Brown ---- Fayetteville
A. M. Davis ---- Fayetteville
C. J. Finger ---- Little Rock
C. L. Garey ---- Fayetteville
G. A. Hale ---- Burdette
D. A. Hinkle ---- Fayetteville
C. A. Hughes ---- Russellville
L. M. Humphrey ---- Scott
J. F. Jacks ---- Osceola
L. P. Johnson ---- Little Rock
T. H. Johnston ---- Stuttgart
U. S. Jones ---- Little Rock
M. Lawson ---- Conway
E. O. McLean ---- Fayetteville
P. E. Smith ---- Fayetteville
A. E. Spooner ---- Fayetteville
R. D. Staten ---- Fayetteville
M. H. Summerour ---- Yellville
P. Talley ---- El Dorado
R. L. Thurman ---- Fayetteville
B. A. Waddle ---- Fayetteville
G. A. Wakefield ---- Little Rock
J. O. Ware ---- Fayetteville

CALIFORNIA

G. H. Abel, Jr. ---- Brawley
D. G. Aldrich, Jr. ---- Riverside
R. W. Allard ---- Davis
L. E. Allison ---- Riverside
E. G. Anderson ---- Pasadena
R. J. Arkley ---- Modesto
L. E. Arnold ---- Fresno
V. S. Aronovici ---- Pomona
W. W. Austin ---- Berkeley
J. D. Axtell ---- Bakersfield
A. D. Ayers ---- Riverside
K. L. Babcock ---- Berkeley
C. G. Barr ---- San Jose
H. M. Barron ---- Wasco
I. Barshad ---- Berkeley
H. M. Benedict ---- Stanford
S. H. Bierly ---- San Marino
F. T. Bingham ---- Riverside
E. S. Bliss ---- Bakersfield
G. B. Bodman* ---- Berkeley
L. F. Bothwell ---- Woodland Hills
C. A. Bower ---- Riverside
R. L. Branson ---- Riverside
F. N. Briggs* ---- Davis
F. E. Broadbent ---- Davis
A. L. Brown ---- Davis
J. W. Brown ---- Riverside
L. N. Brown ---- Berkeley
G. A. Cahoon ---- Riverside
P. D. Caldis ---- San Leandro
J. W. Cameron ---- Riverside
H. D. Chapman ---- Riverside
C. E. Claassen ---- Woodland
W. M. Clement, Jr. ---- Davis
M. G. Cline* ---- San Francisco
E. A. Colman ---- Berkeley
J. P. Conrad ---- Davis
D. R. Cornelius ---- Berkeley
L. E. Davis ---- Davis
P. R. Day ---- Berkeley
G. T. Den Hartog ---- Shafter
D. D. Dickenson ---- Tracy
K. D. Doak ---- San Francisco
W. E. Domingo ---- San Diego
L. D. Doneen ---- Davis
M. Donnelly ---- Riverside
T. W. Embleton ---- Riverside
R. C. Erwin ---- Mountain View
I. Fatt ---- La Habra
M. Fireman ---- Riverside
J. R. Fisher ---- Berkeley
C. L. Fly ---- San Francisco
J. R. Furr ---- Indio
R. A. Gardner ---- Berkeley
C. A. I. Goring ---- Seal Beach
K. D. Gowans ---- Red Bluff
L. R. Hac ---- Woodland
R. M. Hagan ---- Davis
R. B. Harding ---- Riverside
C. Hargreaves ---- Riverside
W. G. Harper ---- Riverside
F. Harradine ---- Alameda
H. A. Hawthorne ---- Davis
H. E. Hayward ---- Riverside
J. B. Hemwall ---- Seal Beach
K. Hernlund ---- Goleta
J. M. Heslep ---- Sacramento
E. A. Hockett ---- Davis
A. Hoffman ---- Stockton
C. R. Horton ---- San Francisco
M. Huberty ---- Los Angeles
R. Hutchings ---- Salinas
H. Jenny* ---- Berkeley
C. E. Johnson ---- Bakersfield
F. R. Johnson ---- San Mateo
R. T. Johnson ---- Spreckels
W. M. Johnson ---- Berkeley
L. G. Jones ---- Davis
H. A. Joseph ---- Riverside
W. P. Kelley* ---- Berkeley
E. M. Kitchen ---- Los Angeles
J. E. Knott ---- Davis
P. F. Knowles ---- Davis
I. K. Landon ---- San Francisco
M. H. Lapham ---- Oakland
K. H. Larson ---- Los Angeles
H. M. Laude ---- Davis
F. H. Leavitt ---- San Francisco
J. H. Lindt, Jr. ---- Yuba City
O. A. Lorenz ---- Davis
R. M. Love ---- Davis
R. L. Luckhardt ---- Los Angeles
O. R. Lunt ---- Los Angeles
J. N. Luthin ---- Davis
A. W. Marsh ---- Riverside
J. C. Martin ---- Berkeley
J. P. Martin ---- Riverside
W. E. Martin ---- Berkeley
M. E. McCollam ---- San Jose
R. C. McColloch ---- Riverside
M. E. McCreery ---- Beverly Hills
S. C. McMichael ---- Shafter
J. L. McMurdie ---- Berkeley
D. S. Mikkelson ---- Davis
J. W. Neel ---- Santa Monica
J. H. Nelson ---- Stockton
R. E. Nelson ---- Riverside
T. R. Nielsen ---- Davis

* Fellow, American Society of Agronomy.

A. B. Nielson	Burlingame
W. E. Nyquist	Davis
G. Ogata	Riverside
O. C. Olson	Red Bluff
V. P. Osterli	Davis
F. G. Parsons	Davis
G. A. Pearson	Riverside
E. P. Perry	Berkeley
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A. T. Corey ---- Gibsonia
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The Chlorophyll Content of Certain Flue-Cured and Turkish Tobacco Varieties[1]

Frederick A. Wolf and Frederick T. Wolf[2]

SINCE no one has determined the chlorophyll content of flue-cured varieties and Turkish varieties of tobaccos, it is the present purpose to provide such data and to discuss their usefulness. It should be pointed out, however, that Griffith, Valleau, and Jeffrey (5) determined the chlorophyll content of 7 varieties of dark tobaccos and that of 11 of Burley varieties. The dark varieties were found to contain 13.1 to 18.7 mg. of total chlorophylls per gram on a dry weight basis, the average being 16.2 mg./g. The 11 Burley varieties had 7.7 to 14.8 mg./g., averaging 10.6 mg./g. The average proportion of chlorophyll *a* to chlorophyll *b* was 69.2 to 30.8 respectively in the dark tobaccos and 69.9 to 30.1 in the Burley varieties.

Subsequently Jeffrey and Griffith (6) studied the changes in concentrations of chlorophylls during air curing of the Burley variety Kentucky 16. They used 3 sets of samples, one from plants cut 10 days before maturity, another when mature, and the third when 10 days overmature. The samples were wilted for 24 hours and then cured under controlled conditions of temperature and relative humidity. Basal leaves and upper leaves from each set of samples were removed at intervals during a period of 39 days and were analyzed. They found the highest rates of chlorophyll loss in the basal leaves of immature plants. Moreover, chlorophyll *a* constituted only 57 to 60% of the total chlorophyll at the end of the air curing process, having declined from 71 to 73% at the time of harvest. These results confirmed the earlier conclusions (5) that "chlorophyll *a* is less stable than chlorophyll *b*. . . . The percentage of *a* tends to decrease during the curing of tobacco, which is in many respects a continuation of the changes going on during the maturation of the leaf".

MATERIALS AND METHODS

Twelve varieties of tobacco were studied. The 5 Turkish varieties included 9, a Smyrna type; 15A and 15, of Samsoun type; 18, a Xanthi type; and 20, a Cavalla type. Hicks, Oxford 28, Gold Dollar and Dixie Bright 101 were the flue-cured varieties used. The 2 Burley varieties, Kentucky 16 and White Burley, and a single dark tobacco, Madole, were also included for comparative purposes. All were grown under field conditions at the Tobacco Experiment Station, Oxford, N. C., during the 1954 season. Commercial fertilizers were applied in amounts to yield best quality at this location.

Three different types of samples were analyzed. In one of these, referred to subsequently as green or normal tobacco, leaves of mature size were picked, although these would have been regarded as immature by an experienced grower. The second type of samples, referred to hereafter as mature, were collected at the time when the leaves would have been harvested or primed by an experienced grower. The third type of samples, designated yellow, were likewise collected when ripe, but were thereafter allowed to yellow for a period of 44 to 66 hours before analysis. The series of green samples were harvested between July 9 and Aug. 9; the mature samples, between Aug. 6 and Aug. 12; and the yellow samples, between Aug. 16 and Sept. 2.

Except for the leaves which were allowed to yellow, 10-g. samples were used in chlorophyll analyses; these were made on the same day as that on which the leaves were removed from the plants. Usually the analyses were completed within 6 hours from the time of collection. Because of water loss during the yellowing process, which ranged in amount from 5 to 10%, the leaves used in these determinations were weighed shortly after picking, and again after yellowing, the sample consisting of the equivalent of 10 g. of the original net, fresh weight.

The chlorophyll analyses were performed by a method only slightly modified from that of Comar (2) and Comar and Zscheile (3), and as reported in the A. O. A. C. Official Methods of Analysis (1). The selected sample of fresh leaf tissue was ground in a Waring blendor in acetone containing a small quantity of $CaCO_3$. The acetone solution of the pigments was removed by suction filtration, and the filtrate was made up with additional acetone to a volume of 200 ml. A 12.5-ml. aliquot of the acetone solution was mixed in a separatory funnel with 50 ml. of ethyl ether. The pigments were transferred to the ether layer upon the addition of distilled water. The ether solution was washed repeatedly with water, was made up to a volume of 100 ml., and was then dried by the addition of anhydrous Na_2SO_4.

Determinations of the optical density of the ether solution of the chlorophylls were made with a Model DU Beckman spectrophotometer. The optical density of each sample was measured at 6425 Å and at 6600 Å, corresponding to the maxima in the absorption spectra of chlorophyll *b* and chlorophyll *a*, respectively. The concentrations of chlorophyll *a* and *b* were then computed from the equations:[3]

[3] Consult Comar and Zscheile (3) for derivation of the formulae.

$$\mathrm{Ch}\,a = 9.93 \log \frac{I_0}{I}\,(6600) - 0.777 \log \frac{I_0}{I}\,(6425)$$

$$\mathrm{Ch}\,b = 17.6 \log \frac{I_0}{I}\,(6425) - 2.81 \log \frac{I_0}{I}\,(6600)$$

All values are reported on the basis of mg./g. fresh weight. Considerations of the size of sample used, the volume of acetone, the volume of the aliquot of the acetone solution, and the volume of ether used indicated that the values obtained in the above equations must be multiplied by a factor of 0.16 to give the chlorophyll concentrations in mg./g. Values for total chlorophylls and for percentage of chlorophyll *a* were then calculated from the primary data.

RESULTS

The results of analyses for chlorophyll *a*, chlorophyll *b*, total chlorophylls, and percentage of chlorophyll *a* in the green leaves of 12 tobacco varieties are presented in table 1. Each value in the table represents the average of determinations performed on 10 or more different collections.

[1] Received Jan. 22, 1955.

[2] Emeritus Professor of Botany, Duke University, Durham, N. C., and Associate Professor of Botany, Vanderbilt University, Nashville, Tenn.

Table 1.—The chlorophyll content of the green leaves of 12 varieties of tobacco.

Variety	Chlorophyll a mg./g.	Chlorophyll b mg./g.	Total chlorophylls mg./g.	Chlorophyll a %
18	1.17 ± .13	0.49 ± .07	1.66 ± .18	70.7 ± 1.7
Hicks	1.05 ± .14	0.46 ± .06	1.51 ± .20	69.6 ± 1.4
Madole	1.03 ± .11	0.45 ± .07	1.48 ± .18	70.0 ± 2.1
Oxford 28	0.96 ± .14	0.40 ± .06	1.36 ± .20	70.8 ± 0.9
Gold Dollar	0.82 ± .24	0.36 ± .11	1.17 ± .34	69.7 ± 1.9
9	0.81 ± .09	0.35 ± .03	1.16 ± .11	69.8 ± 1.6
15A	0.76 ± .08	0.34 ± .04	1.10 ± .12	69.3 ± 2.1
15	0.73 ± .09	0.34 ± .05	1.06 ± .14	68.6 ± 2.1
20	0.66 ± .07	0.28 ± .03	0.95 ± .08	70.0 ± 2.0
D.B. 101	0.60 ± .07	0.28 ± .04	0.88 ± .11	68.4 ± 2.1
Kentucky 16	0.43 ± .07	0.19 ± .05	0.62 ± .10	69.8 ± 3.7
White Burley	0.38 ± .04	0.16 ± .03	0.54 ± .06	70.0 ± 3.1

Values for the standard deviations have also been included. Calculations for each of the 120 or more determinations summarized in this table have been computed to three decimal places, but were rounded off to the closest 0.01 mg. per gram fresh weight, thus yielding, in certain instances, values for total chlorophylls which differ slightly from the sum of the figures for chlorophyll *a* and chlorophyll *b*.

There is a difference of approximately 300% in total chlorophyll content between White Burley, which had the least chlorophylls (0.54 mg./g.), and the Turkish variety 18, which had the most (1.66 mg./g.). Both of the Burley varieties studied, Kentucky 16 and White Burley, have less chlorophyll than the variety Madole, thus confirming the finding of Griffith, Valleau, and Jeffrey (5). Among the Turkish varieties, 18 is exceptional in its large quantity of chlorophylls. The remaining Turkish varieties studied had less chlorophylls than any of the flue-cured varieties, with the exception of Dixie Bright 101. The average of the flue-cured kinds is considerably higher than the average of either the Burley or Turkish varieties.

No significant differences were found in the percentage of chlorophyll *a* present in the 12 varieties studied, since it varied only from 68.4 to 70.8%.

The findings from analyses of the chlorophyll content of the mature leaves of 7 varieties are presented in table 2. Each value shown represents the average of 4 determinations on different samples. By the time the leaves are ready to be harvested, the quantity of chlorophyll in all varieties taken together has declined by an average of 46.6%. A significant difference is to be noted in this connection between the flue-cured varieties, on the one hand, and the Madole and Burley varieties on the other, the decrease in total chlorophylls being much more pronounced in the flue-cured varieties.

Concomitant with decrease in total chlorophyll content associated with maturity is a change in the proportion of the two chlorophyll components. Chlorophyll *a* is more readily destroyed than chlorophyll *b*. In the green leaves of the 7 varieties studied, the over-all average percentage of chlorophyll *a* was 69.8%. This amount decreased to an average of 61.8% at maturation. These results, similar to those reported by Jeffrey and Griffith (6) for the Burley variety Kentucky 16 during curing, indicate that the preferential destruction of chlorophyll *a* is a general phenomenon occurring also in other types of tobaccos, and emphasize the fact that this process begins while the leaves are still on the growing plant in the field.

Table 2.—The chlorophyll content of the mature leaves of 7 varieties of tobacco.

Variety	Chlorophyll a mg./g.	Chlorophyll b mg./g.	Total chlorophylls mg./g.	Decrease from normal %	Chlorophyll a %
Hicks	0.40	0.25	0.64	57.2	61.4
Madole	0.55	0.30	0.85	42.3	64.3
Oxford 28	0.34	0.23	0.57	58.2	60.0
Gold Dollar	0.34	0.23	0.57	51.5	60.5
D.B. 101	0.24	0.15	0.39	56.3	61.8
Kentucky 16	0.32	0.18	0.49	22.5	64.0
White Burley	0.20	0.13	0.33	39.5	60.7

Table 3.—The chlorophyll content of the yellow leaves of 7 varieties of tobacco.

Variety	Chlorophyll a mg./g.	Chlorophyll b mg./g.	Total chlorophylls mg./g.	Decrease from normal %	Chlorophyll a %
Hicks	0.08	0.12	0.21	86.2	41.4
Madole	0.24	0.21	0.45	68.6	53.6
Oxford 28	0.09	0.14	0.23	83.1	41.8
Gold Dollar	0.10	0.14	0.24	79.8	41.5
D.B. 101	0.08	0.11	0.19	78.5	43.6
Kentucky 16	0.15	0.17	0.31	49.7	45.6
White Burley	0.07	0.10	0.16	69.6	41.8

In table 3 are presented the findings from chlorophyll analyses of the same 7 varieties after the leaves had been allowed to mature on the plant, had been harvested, and then were allowed to yellow for 44 to 66 hours. Each value in table 3 represents the average of 4 determinations on different samples.

In general, the differences already noted from comparison of green and mature leaves become more accentuated as the leaves yellow. The content of total chlorophylls, originally averaging 1.08 mg./g. in the green leaves of these 7 varieties, decreased to an average value of 0.55 mg./g. in the mature leaves. On yellowing, there is an additional decrease to an average value of 0.26 mg./g. Moreover, the decrease is significantly greater in the flue-cured varieties

than in the dark and Burley varieties, the average chlorophyll content of the 4 flue-cured varieties having decreased by 81.9%.

DISCUSSION

The data reported herein concerning chlorophyll content on a fresh weight basis may be compared with those of Griffith, Valleau, and Jeffrey (5), who expressed chlorophyll concentration of a dry weight basis. But if it is borne in mind that the water content of green and mature leaves on the plant is high, approximating 90%, it becomes apparent that the content of chlorophylls from the two sets of data are of similar magnitude.

Differences between certain varieties in chlorophyll content, when growing in the field, are readily apparent to the eye. Growers tend to harvest Dixie Bright 101, for example, which has a greenish yellow leaf, while the leaves are still immature. Manifestly, a change in content of chlorophylls accompanies the maturing of any given variety, but in flue-cured types, in which lemon-yellow color is of prime importance in quality of the cured leaf, the loss of chlorophylls is greater than in other types. Because difficulty is sometimes encountered in the curing of varieties harvested when immature, and because immature leaves, after aging in storage, are of poorer quality than mature ones, the present findings should be applicable to harvesting practices with flue-cured tobaccos and in future breeding work leading to the development of new varieties.

The variations in total chlorophyll content within certain varieties, such as Gold Dollar, Oxford 28, and Hicks, are considerably greater than those found in other varieties. While these findings may be attributable in part to sampling error, and to differences between varieties in leaf thickness, there is also the possibility, supported to a degree by field observations, that the chlorophyll content is less well stabilized or fixed genetically in certain varieties than in others. Moreover, the genetical factors which control production of chlorophyll are known to be modified by the supply of nitrogen available to the growing plant, for when the supply is excessive the leaves are dark green, and when meagre, they are pale green.

As pointed out (5), "studies on pigment disappearance are rare", and the phenomenon is little known. Certain data indicating upset of genetical controls and consequent occurrence of increase of chlorophyll above normal or decrease below normal come from studies involving tobacco diseases. Disappearance of chlorophyll and inhibition of its formation in tobacco, as induced by certain viruses, have been studied by Dunlap (4) and Peterson and McKinney (7). Dunlap found that a normal plant, having a total leaf area of 89.7 sq. dm., contained 359 mg. of chlorophyll, whereas a mosaic plant, having a total leaf area of 62.6 sq. dm., contained 221 mg., i.e. 62% as much as the normal plant. Peterson and McKinney found that the chlorophyll content of tobacco leaves affected with common mosaic, yellow mosaic, dark-green mosaic, and mild mosaic was consistently lower than that of normal leaves and that the chlorophyllase activity in virus-affected leaves, except common mosaic, was always higher than in normal leaves.

SUMMARY

The quantities of chlorophyll *a* and chlorophyll *b* in the green leaves of 12 tobacco varieties, including Turkish, flue-cured, and Burley types, and a dark type, have been determined by a spectrophotometric method. Total chlorophylls of the varieties sampled vary from 0.54 to 1.66 mg. per gram of fresh weight. With some exceptions, the flue-cured varieties have a higher content than the Turkish varieties, and these contain more chlorophylls than the Burley types. No significant difference was found in the percentage of chlorophyll *a* among varieties, the range being from 68.4 to 70.8%.

The chlorophyll content of four flue-cured, two Burley, and one dark variety has also been determined in mature leaves, and in leaves yellowed during the initial stages of curing. The average decrease of total chlorophyll content was 46.6% in the mature leaves and 73.6% in the yellow leaves. Such decrease is more pronounced in the flue-cured than in dark or Burley varieties. The significance of greatest chlorophyll loss in flue-cured types is discussed.

A preferential destruction of chlorophyll *a* accompanies the changes which occur in mature and yellow leaves. The percentage of chlorophyll *a* is 69.8% in green leaves, but is reduced to 61.8% in mature ones and to 44.2% in the yellow leaves.

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Factors Affecting Fruit Development of the Jumbo Runner Peanut[1]

G. M. Shear and L. I. Miller[2]

TO INTERPRET peanut yields, it is essential to understand the factors that affect the development of the peanut (*Arachis hypogaea* L.) fruit. The most comprehensive study on this subject was made by Shibuya (5) with large seeded runner and small seeded Java Bunch peanut. Certain phases of peanut fruit development have been reported by Pickett (3) for Virginia Bunch, by Patel and Seshadri (2) for a Spanish variety, and by Smith (7) for Virginia Jumbo Runner peanuts. In all lines of research based on fruit yield and quality, in which the Jumbo Runner variety of peanut has been used, the need for more information about the factors that affect fruiting has become increasingly important.

This study is part of a more comprehensive project dealing with factors affecting fruit development and yield. The first phase dealt with the effects on fruiting of peg removal during different intervals in the blooming period. It soon became apparent that only very limited information could be obtained from peg removal experiments and peg tagging was resorted to for determining the effect of time of fruit initiation on fruit development. A preliminary report on part of this study was presented in 1950 (4).

METHODS

Seed from a single plant selection of the Holland strain (1) of Jumbo Runner peanut was used in 1949 and this selection was rogued annually in order to maintain a uniform seed stock for subsequent plantings.

Leaf shedding, resulting from infections of *Cercospora arachidicola* Hori and *C. personata* (B. and C.) E. and E., was controlled by repeated applications of sulphur to the foliage. The Southern corn rootworm (*Diabrotica duodecimpunctata howardii* Barb.) was controlled through the use of lindane in 1949 and 1950, and with aldrin in 1951 and 1952.

In the experiment to determine the effect of peg removal on yield and fruit development, pegs were removed by clipping them before they reached the soil. Thus the fruit development was restricted to that fruit produced from pegs formed at certain intervals during the fruiting period. A peg according to Smith (6) is the stalk-like appendage produced from the point of flower attachment, after flowering but before fruit enlargement. When clipping was done during a given period, it was done at weekly intervals, and all pegs produced during the preceding week were removed. The field plots consisted of 4 plants each, spaced 3 feet apart. A randomized block design was used and each treatment was replicated 6 times. The plots were located on Onslow sandy loam soil at the Tidewater Field Station, Holland, Va.

The rate of development of fruit from flowers produced at different times during the flowering period was studied by marking 10 newly formed pegs per plant, at weekly intervals. In order not to disturb previously marked pegs, the pegs farthest from the crown of the plant were marked each time. These plants were spaced 3 feet apart with 4 plants per plot. Three plots selected at random were harvested at weekly intervals over a period of several weeks, starting in late September. The development of fruit from pegs tagged at each tagging period was measured. Plastic chicken leg bands were placed around the pegs to be identified; each week different colored bands were used. In 1950, the bands were slipped over the pegs just as they reached the soil, and it was assumed that the developing fruit would prevent the bands from being lost at harvest. However, a high percentage of the bands fell off either before the fruit enlarged or because the fruit failed to develop. During the next two seasons the bands were wired to the plants to prevent their loss.

RESULTS

Pegs were removed by clipping during three different periods in 1949. On one set of plants, pegs were clipped from the time the first ones were observed in early July until July 26, and on another set from early July until Aug. 23. On a third set of plants the newly formed pegs were first removed on Sept. 3, which included pegs developing from flowers produced during the preceding 10 days, and then were removed weekly until harvest. The number of large fruit (fruit retained by a screen with slots 36/64-inch in width) per plant at harvest was not altered by the removal of all pegs from the beginning of peg formation until July 26 or until Aug. 23; see table 1. These results show that the plants developed a comparable number of fruit even though the start of fruit formation was delayed for different lengths of time by peg removal. The maturity of the fruit, however, is related to the length of the period during which it developed, as is shown by the data. The weight of fruit (pod and seed) and seed was lowered by peg removal during both periods. The shelling percentage (ratio of fruit weight to seed weight) was lower from plants with pegs removed until Aug. 23, than from plants with pegs removed until July 26 or from undisturbed plants. The weight of extra large seed (seed retained by a screen with slots 22/64-inch in width) was lowest from plants with pegs clipped until Aug. 23, was intermediate from plants with pegs clipped until July 26 and highest from undisturbed plants.

Plants from which the pegs were clipped weekly throughout the period of peg formation produced a few early fruit close to the taproot. These fruit contained extra large seed comparable in weight to those produced by plants the pegs of which were clipped through Aug. 23. This would explain the presence of any extra large seed on this group of plants, since seed of this size would not be expected from pegs produced after Aug. 23.

Pegs were removed by clipping during 4 different periods in 1950. The pegs were clipped from the time the first ones were observed in early July until July 26, on one set. Since it was apparent from the 1949 data that fully developed fruit could not be expected from plants when the pegs were kept clipped until the latter part of August, this treatment was not used in 1950. The newly formed pegs on other sets of plants were first removed on Sept. 1, Sept. 14, and Oct. 1, and then removed weekly until harvest. No differences occurred in the number of large fruit, weight of fruit, weight of seed, or in ratio of seed weight to fruit weight; see table 2. The weight of extra large seed was reduced by clipping the pegs through July 26.

Late clipping in 1949 reduced the number and also the weight of fruit, although the shelling percentage and weight of extra large seed were not affected. In 1950, late clipping did not reduce the number or weight of fruit. These discrepancies may possibly be explained by the dif-

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Table 1.—Effects of peg clipping on fruit development, 1949.

Treatment	No. large fruit per plant	Wt. large fruit per plant (grams)	Wt. of seed per plant (grams)	Wt. seed/wt. fruit (shelling percentage)	Wt. extra large seed per plant (grams)
No clipping	112a*	171.3a	120.3a	69.7a	31.2a
Pegs clipped through July 26	91a	128.2b	89.0b	68.8a	17.5b
Pegs clipped through Aug. 23	101a	118.1b	76.5b	64.6b	5.0c

* There is not a significant difference (5% level) between values in a column that are followed by the same letter.

Table 2.—Effects of peg clipping on fruit development in 1950.

Treatment	No. large fruit per plant	Wt. large fruit per plant (grams)	Wt. of seed per plant (grams)	Wt. seed/wt. fruit (shelling percentage)	Wt. of extra large seed per plant (grams)
No clipping	98a*	200.9a	134.2a	66.8a	73.9a
Pegs clipped through July 26	102a	184.3a	119.2a	64.7a	48.6b
Pegs clipped Sept. 1 to digging	94a	200.4a	137.3a	68.4a	83.0a
Pegs clipped Sept. 14 to digging	102a	196.1a	129.6a	66.2a	69.8a
Pegs clipped Oct. 1 to digging	95a	197.2a	134.5a	68.2a	81.3a

* There is not a significant difference (5% level) between values in a column that are followed by the same letter.

ferent means of peg removal during the 2 years. Peanut pegs are very tough and fibrous and are difficult to cut readily. In 1949, several kinds of clippers were used, all of which resulted in excessive disturbance of the pegs already in the soil. This could easily have reduced the number of later formed pegs developing fruit. In 1950, serrated bone shears were used; these cut the pegs very easily, resulting in no appreciable disturbance to the plants.

The effect of time of peg initiation on the percentage of pegs producing fruit is shown in figure 1-A. A fruit was arbitrarily considered developed when it was retained on a screen with slots 22/64-inch in width. The trends for both 1951 and 1952 were the same, with over 70% of the pegs developing fruit when they were formed by the middle of July. The percentage decreased with each succeeding weekly period of peg formation until by Aug. 19 only 15% of the pegs had formed fruit. The effect of this decrease on yield would be dependent upon the number of pegs produced during a given weekly period. Since the flowering period of this variety of peanut normally extends from late June until September, the period of maximum bloom as related to fruit development and yield is important. Flower counts made in 1952 show a high average daily flower production from mid-July to mid-August, after which flowering decreases quite rapidly; thus, during the period covered by the data in figure 1A, a high and relatively uniform flowering rate was maintained. Smith's data (7) for Virginia Jumbo Runner peanuts support these findings and Shibuya (5) found that the percentage of pegs in relation to flowers remains fairly constant during the main flowering period. Thus, the rate of increase in number of fruit produced from flowers blooming during the first half of August would decline as compared with a comparable period in mid-July.

Another requirement for fruit development in the peanut is that the peg enter the soil (5). The question arises as to whether or not the decrease in the number of pegs developing fruit as the season progresses is due primarily to the failure of pegs to enter the soil. In the peg tagging tests reported here, no record was made of why pegs failed to

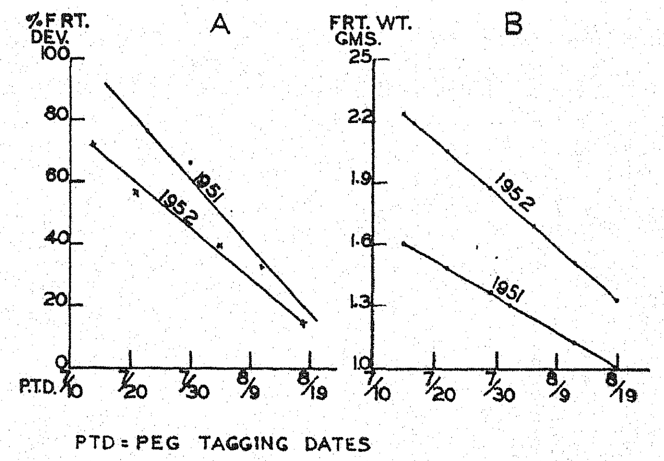

FIG. 1. A.—The effect of time of peg formation on the percentage of pegs producing fruit.

B. Linear regression of fruit weight on time of fruit initiation after linear adjustment to constant age (8 weeks in 1951, 9 weeks in 1952).

produce fruit. In 1952, however, lots of 10 plants grown at 1-foot spacing and 10 others at 3-foot spacing were dug each week starting July 17 and continuing for a 7-week period to study peg development. Counts were made of pegs that had and those that had not entered the soil. Pegs that enter the soil are easily distinguished by their white tips. Differences in spacing did not affect the percentage of pegs entering the soil. There was a significant increase in the percentage of pegs entering the soil as the season progressed. On July 17, 62% of the pegs had entered the soil, and on Aug. 27 the percentage had increased to 86. This was evidence that the decrease in percentage of pegs developing fruit as the season progressed could not be attributed to failure of pegs to enter the soil.

Shibuya (5) presents data for small seeded bunch peanuts, showing that the percentage of pegs in the soil decreased from 65% at 9 weeks after planting to 26% after

17 weeks. He attributes the higher fruiting rate of early formed pegs to the higher number penetrating the soil. This does not appear to be a logical assumption since even after 17 weeks he found a surplus of pegs in the soil that did not develop fruit. He presents a diagram of a large seeded runner peanut plant showing the time each flower opened and which flowers produced fruit. The peak of fruit production was from flowers opening during the third and fourth weeks of the flowering period. This corresponds with the period covered by the two highest values for percentage of fruit developed, as shown in figure 1A.

The data in table 3 show the effect of time of initiation and age of fruit on fruit weight. The weight of fruit of a comparable age is affected by the time of its initiation. Fruit developing from flowers produced during the early part of the flowering period grows most rapidly while fruit developing from later flowers grows progressively slower. Figure 1B was obtained by fitting a linear regression formula and shows the relative weight of fruit of a uniform age at harvest (8 weeks in 1951, 9 weeks in 1952), the pegs of which were tagged on the indicated dates. It shows a decrease in growth rate of 0.124 grams per week in 1951 and 0.180 grams per week in 1952.

The data in table 4 show the mean temperatures during the different periods when fruit development rates were obtained. These data show a close correlation between decreasing temperature and decreasing growth rate of later-formed fruit. While temperature is unquestionably an important factor in the growth rate of the fruit, other factors such as decreasing day length, declination of the sun, and the presence of older fruit may also be contributing to the reduced growth rate of later-formed fruit.

Table 3.—The average weight of peanut fruit of different ages developed from pegs produced at different times during the fruiting period. Values on a given diagonal line represent the weight of fruit of the same age developing from pegs produced at different periods during the fruiting season.

DIG. DATES	1951 PEG TAGGING DATES 7/15	7/22	7/29	8/5	8/12	8/19	AGE WKS.
	GMS.	GMS.	GMS.	GMS.	GMS.	GMS.	
9/10	1.70	1.27	1.07	.80	.33	.23	3
9/17	1.90	1.47	1.20	.93	.53	.43	4
9/24	2.17	1.57	1.13	.90	.57	.37	5
10/1	2.27	1.60	1.30	1.00	.83	.87	6
10/8	2.60	2.10	1.67	1.73	1.13	1.03	7
10/15	2.37	2.10	1.90	1.70	1.10	1.17	
	13	12	11	10	9		8
	1952						
9/18	2.40	1.97	1.67	1.47	1.13	1.33	4
9/27	2.13	2.17	1.90	1.40	1.30	1.23	5
10/2	2.50	2.33	1.90	1.70	1.60	1.27	6
10/9	2.50	2.13	2.30	1.57	1.73	1.13	7
10/16	2.50	2.37	2.10	2.07	1.67	1.37	8
10/23	2.27	2.10	2.17	1.73	1.60	1.07	
AGE WKS	14	13	12	11	10		9

DISCUSSION

It can be seen from the data presented here that under field conditions at Holland, Va., (latitude 36° 41′, longitude 76° 47′, elevation 80 ft.), the time required for a fruit of the Jumbo Runner peanut to attain its full development from a flower is quite variable. If we arbitrarily consider a fruit weighing 2 g. (about 80% of the average maximum weight) or more as being fully developed, then the time from tagging (approximately 1 week after flowering) to full development would vary as much as 3 weeks, depending upon the time that the flower is produced. Thus, the Jumbo Runner variety would require 10 to 13 weeks to produce a fully developed fruit from a given flower.

Patel and Seshadri (2) found that a Spanish variety peanut growing in India required 60 days from the time of flowering until fruit was mature. Pickett (3) under Georgia conditions found that Virginia Bunch peanuts required 9½ to 11½ weeks to reach maturity (seed weight of 510 mg.) from the flowering stage, when flowers produced early in

Table 4.—The mean temperatures for the periods during which fruit weights in table 3 were produced.

DIG. DATES	1951 PEG TAGGING DATES 7/15	7/22	7/29	8/5	8/12	8/19	AGE WKS.
	°F	°F	°F	°F	°F	°F	
9/9	77.2	76.9	76.4	76.1	76.1	74.5	3
9/16	76.6	76.3	75.7	75.3	75.2	73.8	4
9/23	75.7	75.3	74.7	74.2	73.9	72.5	5
9/30	75.2	74.8	74.2	73.7	73.4	72.1	6
10/7	74.6	74.2	73.6	73.2	72.8	71.6	7
10/14	73.3	72.8	72.1	71.6	71.8	69.8	
	13	12	11	10	9		8
	1952						
9/16	77.5	76.8	75.9	75.1	74.2	72.7	4
9/23	77.2	76.6	75.8	75.1	74.3	73.1	5
9/30	75.9	75.2	74.3	73.5	72.7	71.3	6
10/7	74.9	74.2	73.3	72.5	71.6	70.3	7
10/14	73.5	72.8	71.8	71.0	70.0	68.7	8
10/21	72.6	71.8	70.9	70.0	69.0	67.7	
AGE WKS.	14	13	12	11	10		9

the flowering period were studied. The effect of time of fruit initiation on development was not considered. At the lower latitudes where these two studies were made, a lag in rate of fruit development might not occur or might be less pronounced than was found under Virginia conditions.

SUMMARY

The development of fruit of a selection of the Holland strain of the Jumbo Runner peanut was studied by means of peg removal or peg tagging.

The removal of pegs from the beginning of peg formation until the latter part of August did not reduce the number of large fruit at harvest, although later formed fruit were less mature at harvest. Thus, the number of fruit that peanut plants of a given size will produce appears to be quite definite.

Pegs produced from late August until flowering ceased, on plants which had not been previously disturbed, did not have a significant effect on yield.

The percentage of pegs producing fruit decreases as the flowering period advances. The number of fruit that developed was not limited by a lack of pegs penetrating the soil, but appears to depend on some other factor or factors inherent in the plant.

The rate of fruit growth decreases for later-formed fruit under field conditions, and although the presence of early-formed fruit undoubtedly affects the growth rate of later-formed fruit, a close correlation with decreasing mean temperatures and decrease in growth rate was found.

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Alfalfa Seedling Emergence from Seed Lots Varying in Origin and Hard Seed Content[1]

S. T. Dexter[2]

During the past year or two there has been considerable unrest in the alfalfa seed trade due to advertising which suggests that the hard seed content in alfalfa seed lots is highly detrimental to the success of the seed in the field. Since new techniques and sources of alfalfa seed production have recently been developed, it seemed worthwhile to reinvestigate this old problem.

REVIEW OF LITERATURE

Papers (2, 3, 4, 6, 7, 8, 9) and references (1, 5) summarize many of the investigations of hard seed. It has been suggested repeatedly that a reasonable percentage of hard seed is probably at least as much an advantage as a disadvantage, agronomically speaking. The practice of scarifying alfalfa seed, common perhaps 30 years ago, almost disappeared following articles that showed that such seed lost rapidly in viability. It has been suggested frequently that a sample containing a considerable percentage of hard seed tended to maintain viability longer than a sample low in hard seed.

MATERIALS AND METHODS

Through the courtesy of the Crop Improvement Secretaries of several of the alfalfa seed-producing states, as well as with the assistance of C. S. Garrison, and various seedsmen, 190 lots of alfalfa seed were obtained. In almost every case, a history of the seed lot was furnished, showing the approximate date of harvest, cultural practices, etc.

Several varieties were represented with several samples of each. Most of the seed lots were certified seed, a few were foundation, and the Michigan lots were ordinary commercial samples. Among the lots of seed were several that were picked by hand and hand threshed, furnished by C. M. Rincker of Wyoming, and L. E. Arnold, of California. All except 46 lots were seed harvested in 1953, and only 21 lots were older than 1951 seed.

Samples in each case consisted of 100 seeds. The weight of 100 seeds was determined. Laboratory germination[3] of all samples was carried out during April and May, 1954, and repeated during October and November.[4] Various lots were planted in rows in the field at a depth of about 1/4 inch, on April 9, May 4, June 1, July 1, Sept. 1, and Oct. 1, 1954. Seedlings were counted and usually pulled, within a few days of emergence, until emergence appeared to be essentially complete. Counting of the seedlings of the April, May, June, and July plantings stopped on Aug. 26. With the September and October plantings, counting continued through November.

EXPERIMENTAL RESULTS

April plantings.—Sixty samples representing every state in the test, were planted April 9 in rows, at a depth of about 1/4 inch. Lots were selected without regard for hard seed content, since these figures had not yet been obtained.

There was great variation among the lots in the rapidity of germination, varying on April 23 from 5 to 78 seedings

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Table 1.—Percentage average emergence and survival of 24 lots "quick" and 24 "slow" in germinating, selected from 60 lots of alfalfa seed planted in the field April 9.

	Laboratory germination		Emergence and survival in the field plantings						
	Quick germ.	Hard seed	Emerg. up to Apr. 28	Emerg. up to May 5	Frost survival	Calc. stand on May 18	Later emerg.	Total emerg.	Calc. total living
	%	%	%	%	%	%	%	%	%
Ave. Quick	73	15	44	62	61	38	6	68	44
Ave. Slow	47	41	23	52	76	40	18	70	58

Table 2.—The average field emergence during and after the drought is shown for 24 "quick" and 24 "slow" lots from 60 lots of alfalfa seed planted May 4.

	Lab. hard seed	Field emergence		
		Emergence during drought up to May 28	Emergence when rain came	Total emergence
	%	%	%	%
24 lowest in hard seed, ave.	18	5	17	22
24 highest in hard seed, ave.	35	1	27	28

emerged, and on May 4 from 24 to 91. The remainder of the month of May was exceedingly dry with several consecutive nights below freezing about May 15 and without rain until May 28, when rain was almost continuous for several days thereafter. During the last days of May and the first days of June, there was considerable further germination.

When seedling counts were made, 10 seedlings were left in each row, and the remainder were pulled. From the remaining 10 seedlings in each row, survival was calculated following the frost and drought periods. The 60 lots of seed were planted in 6 blocks of 10 each. Twenty-four lots, 4 from each of the 6 blocks, with the highest total field germination up to May 4 were selected as "quick" in germination. Similarly, 24 lots, 4 from each of the 6 blocks, with the lowest total germination were selected as "slow". The total early germination, the percentage survival after frost, and the total germination during and after the rains in late May are shown in table 1.

The table shows that a total of 68 seedlings emerged per 100 seeds in the 24 "quick" lots, in comparison with 70 for the "slow" lots. The distribution of emergence in relation to freezing and the drought, however, left a calculated 44 living seedlings for the "quick" and 58 for the "slow" lots, since more seedlings in the "quick" lots were killed by frost and drought.

May plantings.—On May 4, 60 lots of seed were planted in 6 blocks of 10 each. The soil was rather dry, but immediately following planting, a brief beating shower dampened the surface, which quickly dried to form a crust. No further rain fell until May 28. In 29 of the 60 cases, no seedlings emerged in the first few weeks. Of the remainder, the 4 highest were 20, 14, 11, and 9 from the 100 seeds.

From the laboratory figures, the 24 samples with the lowest hard seed count and the 24 with the highest hard seed count were selected. Their germination in the field during and after the drought is shown in table 2.

In the May 4 plantings, the crusting of the soil caused the loss of many seedlings, since in many cases, the crust was pushed up but the seedlings failed to emerge because of the continued drought. Apparently this condition was particularly damaging to the lots with a high "quick" germination, although the total emergence was low in most cases on this planting date. The three highest in total emer-

Table 3.—The 30 lowest and the 30 highest out of 90 samples in laboratory hard seed percentage compared in field emergence, from the June 1 planting.

	In laboratory			In field
	Hard seed	Quick	Sum	Total emergence
	%	%	%	%
Ave. of 30 lowest in hard seed	5	71	76	56
Ave. of 30 highest in hard seed	53	49	92	62

Table 4.—Comparison of seed lots planted on July 2.

	Aver. Field emergence		
	July 8	July 8 to Aug. 26	Total
	%	%	%
12 low in hard seed	50	5	55
12 high in hard seed	33	19	52

Table 5.—Field emergence of alfalfa seedlings from seed lots high or low in hard seed, planted Sept. 1.

	Laboratory germination		Emergence in the field			
	Hard seed	Quick germ.	Sept. 17	Oct. 1	Oct. 23	Total
	%	%	%	%	%	%
Lot low in hard seed	7	85	77.1	3.4	1.5	82.0
Lot high in hard seed	45	45	74.3	5.1	1.7	82.1

Table 6.—Laboratory values concerning alfalfa seed from various localities—1952 or 1953 seed.

State	Number of samples	Wt. in mg. per 100 seeds	Quick germ. Ave.		Hard seed Ave.		Sum of quick and hard	
			Spr.	Fall	Apr.	Fall	Spr.	Fall
			%	%	%	%	%	%
Michigan	6	188	60	72	25	17	85	89
S. Dak.	19	191	64	73	25	20	89	93
Idaho	17	210	61	72	29	22	99	94
Utah	36	215	62	70	30	26	92	96
Wyoming	40	216	53	62	34	28	87	88
Wyoming*	10	222	21	28	74	69	95	97
Calif.	1	194	—	84	—	6	—	90
Calif.*	1	174	—	80	—	8	—	88
Calif.	15	201	87	90	8	7	95	97
Nebraska	6	203	69	79	24	19	93	98

* Hand picked and hand threshed. 1954 California seed.

gence were 57, 50, and 41% emergence, while the 3 lowest were 3, 7, and 9% emergence.

June plantings.—On June 1, 90 lots were planted, using all samples not previously included. The soil was damp, and very frequent rains kept it so for weeks. The 30 lots with the lowest hard seed count and the 30 lots with the highest hard seed count in the laboratory germinations were compared as to their performance in the field plantings.

In this group of 90 samples were included (purely by accident) 16 of the 21 lots that were older than 1951 seed. Several of these lots were comparatively low in hard seed count and in the sum of "quick" and "hard" seed. Thus, the field emergence was lower than it might normally have been with "quick" lots. In this planting, a considerable amount of damping off was noticed, which probably accounts for the comparatively low field emergence.

July plantings.—To avoid differences due simply to lack of viability, for the July 2 plantings 12 lots with "quick" laboratory germination were paired with 12 lots with "slow" germination, using seed lots from the same state whenever possible, and using only lots with high total live seed. Soil moisture conditions were excellent for germination. Again, considerable damping off was observed.

September plantings.—It seemed possible that with late summer plantings the characteristic of rapid germination might be of considerable value. On that basis, 13 lots of seed with high germination and low hard seed content were blended in equal amounts. Thirteen lots with high germination and high hard seed count were similarly blended. Fifty rows of each blend were planted on Sept. 1 in the field, in soil that seemed damp enough for germination to occur. However, no rain fell for 2 weeks and the temperatures were unseasonably high. On Sept. 14, no seedlings had emerged. Starting at that time, however, there were 3 days of almost continuous rain. Seedling counts were then made, and on further dates as shown in table 5.

As the table shows, no great difference in field performance was found in the two lots planted in September, in spite of very wide differences in laboratory germination. Perhaps this was due to the fact that the seeds were exposed to high temperature in the soil for a period of 2 weeks, from Sept. 1 to Sept. 14.

October plantings.—Plantings on Oct. 1,—a date considered highly inadvisable in Michigan,—gave, by Oct. 18, a total of 51% emergence with hard seeded lots, and 62% for lots with a small hard seed count. No more than two seedlings emerged in any lot after this date. However, all seedlings were too small to give a productive stand the next spring, even if they should live through the winter.

Table 6 represents summarized data from the laboratory germination studies, and may be somewhat indicative of what may be expected in seed samples from various regions although the numbers of samples from Michigan, Nebraska, and California are small. In the table, all samples received directly from the individual state are included, without regard to variety, etc. None were older than 1952 seed.

The results presented in table 6 are self-explanatory. In the 17 lots of seed from California, the highest hard seed content was 23%.

Table 7 presents data concerning hard seed content in relation to various climatic factors under which the seed was grown or harvested. Although the hard seed content in relation to elevation seems complicated by differences in rainfall, and harvest dates, seed samples from the lower elevations were frequently lower in hard seed than were samples from higher elevation.

Table 7.—Effect of elevation, irrigation, and time of harvest on hard seed content.

State	Factors	No. of seed lots	Rainfall inches	Hard seed average
Calif.	50 ft. elevation	2	18	13
Calif.	150	3	7	8
Calif.	500	4	7	1.5
Calif.	1500	3	10	5.3
Calif.	4000	3	15	15
Wyoming	4000–4500	9	—	27
Wyoming	4500–5000	8	—	38
Wyoming	5000–5600	9	—	41
Utah	Irrigated	21	—	29
Utah	Non-irrigated	9	—	27
Wyoming	Irrigated	37	—	34
Wyoming	Non-irrigated	3	—	35
Nebraska	Irrigated	3	—	9
Nebraska	Non-irrigated	3	—	39
Utah	Irrigated	21	—	29
Utah	Non-irrigated	9	—	27
Idaho	Irrigated	10	—	26
Idaho	Non-irrigated	9	—	26
Utah	First cutting	13	—	25
Utah	Second cutting	14	—	32
Calif.	July–August harvest	7	—	3
Calif.	September harvest	3	—	8
Calif.	Late September	5	—	14

Samples produced under irrigation seem much the same in hard seed count as those produced in dry farming. The first cutting seed in Utah seems significantly lower in hard seed than that from the second cutting. The effect of harvest date in California was much the same as in Utah. If warmer temperatures tend to decrease hard seed,—as indicated by the effect of elevation,—harvesting at a considerably later date, and in cooler weather might well do the same. Several states sent in samples of several varieties of alfalfa seed. The hard seed contents of all samples of Grimm, Buffalo, Ladak, and Atlantic and of a reasonable proportion of unselected Ranger samples are averaged in table 8.

DISCUSSION

It is a matter of common knowledge that when it is difficult to harvest seed because of rain, a considerable proportion of the "quick" germinating seed may be lost through germination in the field, and the viability of the harvested seed may be damaged. Further, the scarification of the seed coat may well be greater when seeds are threshed in a very dry condition, rather than when the straw is damp and tough. The inclusion of somewhat immature seeds may also decrease the percentage germination, as well as the weight of 100 seeds. Thus, the precise characteristics of alfalfa seed would be expected to vary considerably from year to year in various locations. It was apparent in the samples used that the degree of cleaning and removal of small or shriveled seeds had considerable bearing on the weight per 100 seeds, and on percent germination. Thus, the 6 samples from Michigan were not certified seed, but were warehouse samples, and were not yet finally cleaned. Selection of a sample for germination may vary. Mr. Anderson's fall samples appear to have germinated generally slightly better than Mr. Beatty's spring samples from the same lots.

The one sample of California alfalfa seed "in the curl", from L. E. Arnold, hand-threshed in Michigan, is of some

Table 8.—Average hard seed content of samples of various varieties.

Variety	No. of lots	Seed from	Average hard seed %	Range %
Buffalo	15	Iadho, Wyo., Utah	34	7.51
Grimm	13	Idaho, Wyo., Utah	37	12–58
Ranger	29	Idaho, Wyo., Utah, S. Dak.	29	7–49
Ladak	10	Idaho, Wyo., S. Dak.	38	17–58
Atlantic	8	Wyo., Utah	42	27–67

interest when compared with seed threshed with a combine from the same field. In each case the hard seed content was low. If these seed lots were cleaned equally to remove shrivelled seed, it seems likely that they would be indistinguishable. This result is in sharp contrast with the seed furnished by Mr. Rincker, from Wyoming, where hand-threshed lots were exceedingly high in hard seed count in comparison with combined samples.

During late September and early October, accidental storage of 100-seed packets of 37 lots of seed occurred for 2 or 3 weeks on the rear ledge in an automobile. Here they were exposed to high temperatures from the sun. The hard seed in these samples was reduced from an average of 33% to 1.2%. Rincker (6) describes his experiments with heat treatments that have similarly reduced the hard seed in legume seeds.

The spring and fall germination tests, about 6 months apart, indicated no rapid falling off in germination in the samples that were low in hard seeds. Practically all samples decreased in hard seed content.

The laboratory differences in hard seed percentage were generally observable in field behavior, although there were plenty of exceptions. In the field, these differences were generally moderated, as illustrated in the results shown in table 1 or table 5. In the course of a few days or weeks, hard seeds became permeable and germinated, in most cases. The advantage of hard seeds, in patching up the damage done by injurious freezing, is well illustrated by the April planting. The extreme drought that the May planting encountered, following a slight shower, almost completely destroyed many stands that had sufficient moisture for partial germination, but not enough for emergence. Although almost all lots were severely injured, lots with high percentages of hard seed produced fair stands when rain came about a month after planting.

Drought occurred for 2 weeks after planting in September, but both lots, high or low in hard seed, germinated well when rain came, giving 82% emergence in each case.

The complications encountered in field-planting,—whether of drought, frost, or crusting of the soil,—in this region are sufficient to give hard seed in alfalfa considerable agricultural value. Extremely high percentages sometimes seemed objectionable, although there appears to have been no case where even the hand-threshed samples from Wyoming with as much as 80% hard seed actually failed to give a reasonably good stand. It seems reasonable to suppose that there are places where quick germination would be a decided advantage, as in mild climates on irrigated land. In this experiment, the advantages of samples with considerable hard seed were not sufficient to justify any serious agronomic objections to seed of low hard seed

content in most cases. Nevertheless, the hard seeds provided a considerable insurance against late frost and other field hazards, and never failed to give a good stand under conditions where the "quick" germinators were successful. With samples having few or no hard seeds, there were occasional examples of almost complete failure to establish a stand.

The effect of several climatic factors may be mentioned. There appeared to be a lower hard seed content in lots from low elevations than in those from high. Seed harvested late, in cool weather, appeared to have a higher hard seed content than seed harvested in warmer weather, earlier in the season. Seed from irrigated land seemed much the same as seed from dryland in the same state, but there is some suggestion that seed from irrigated areas had less hard seed than did seed from humid areas.

The percentage of hard seed in seed lots of various varieties from comparable regions seemed much the same, although Ranger may have a significantly lower average than some of the other varieties. In any case, the hard seed content in every variety was highly variable and unreliable for no apparent reason.

SUMMARY

One hundred ninety samples of alfalfa seed were collected from several states to include a wide range of climatic conditions. These were tested for germination and for hard seed content in the laboratory in the spring and again in the fall of 1954. All lots were planted in the field, at intervals, including planting dates in April, May, June, July, September, and October. The field and laboratory behaviour of samples high and low in hard seed content were compared. Heavy spring frosts and two periods of drought gave opportunity for study of survival under the natural hazards of field planting. Hard seed provided considerable insurance under these adverse conditions. A comparison of hard seed content of samples from the various states and of various varieties and growing conditions was made. Seed from low altitudes tended to be lower in hard seed content than seed from higher altitudes, and second cutting or late-harvested seed seemed somewhat higher in hard seed than first cutting or early-harvested. Seed from irrigated fields seemed much the same in hard seed content as seed from dry-farming fields. Varietal differences in hard seed content were small and unreliable.

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Influence of Soil—Profile Characteristics Upon the Distribution of Roots and Nodules of Alfalfa and Sweetclover[1]

R. L. Fox and R. C. Lipps[2]

THE methods of root study developed by Weaver and Darland (16) have been used to investigate the distribution of grass and corn roots in relation to soil properties (2, 3). In the present investigation these methods have been used for relating legume nodule and root distribution to soil profile characteristics. Special emphasis has been given available phosphorus, and calcium saturation of soil colloids. Calcium and phosphorus are of special interest since both are frequently deficient for legumes growing in soils of the humid regions.

REVIEW OF LITERATURE

Soil pH and percent calcium saturation of soil colloids have been given special emphasis as factors affecting legume root distribution and development. The roots of a single plant may be divided, part in acid soil and part in well limed soil, and the differences in nodulation of the two parts can be shown to be as great as on individual plants grown separately in the respective soils (1, 7). Little or no radioactive calcium was moved from tomato roots supplied with this isotope to roots of the same plant not so treated (13). Neither is calcium readily translocated downward through a root system (14). A number of investigators (7, 10, 12) have grown legumes in soil with one or more strata limed. Fibrous roots and nodules were largely concentrated in the limed area.

The effect of phosphorus on root growth has been investigated much less extensively than has calcium although an improvement in nodulation by phosphorus has been reported (5).

The activity of alfalfa roots at considerable depth has been demonstrated by deep sampling (4); by measurement of soil phosphorus utilization (9); by observing the effect of deep fertilization with nutrient solution (11); and by measurements of soil moisture utilization (8).

It is difficult to segregate the various physical and chemical factors which influence root distribution and penetration. Woodruff and Smith (18) have demonstrated the necessity of placing plant nutrients into infertile claypan horizons before roots can be made to grow there with vigor. Their results indicate that the lack of lime in a Putnam subsoil is of greater significance than is its poor physical condition. Synthetic soil conditioners have been used to

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establish varying degrees of aggregation in loessial top soil and parent material (6). The study indicated increased root growth and nodulation of alfalfa seedlings as a result of an increase in size of aggregates.

METHODS

Sampling and Analysis

Samples of alfalfa and sweetclover root systems were obtained from selected field locations using modifications of a method described by Weaver and Darland (16). These modifications consisted of the use of a sampling box having a larger cross sectional area (5 by 10 inches). This facilitated sampling to considerable depths without the loss of important roots outside the soil column. The back of the sampling box was covered with ½-inch mesh hardware cloth which permitted washing from both above and below. The bottom end of the sampling box was fitted with a steel plate with a cutting edge, which permitted jacking the sampling box onto the soil column. Small clods from the face of the column may fall to the bottom of the sampling box and will prevent a snug fit unless they are moistened with a small quantity of water. For this purpose it is best to remove the wooden back from the sampling box while it is being fitted to the soil column. The soil column was held firmly in the sampling box by winding small cord about the sampling box and soil column. A good practice is to sever the soil column from the trench wall from the surface downward, winding securely with cord as the operation proceeds toward the bottom of the column. The washing process is often aided by pre-soaking the soil column. A suitable tank can be made of asphalt building felt folded up to form sides and ends. Plywood covered with cotton outing flannel, dyed black, is suitable for mounting roots. Wide rubber bands make convenient depth markers.

Phosphorus was extracted with Bray No. 1 extracting solution (0.03 N NH_4F + 0.025 N HCl). Cation exchange capacity was determined by a Kjeldahl determination of adsorbed NH_4^+ after leaching with neutral normal ammonium acetate. Ca, Mg, and K in the ammonium acetate leachate were determined using a Beckman DU spectrophotometer with an oxy-hydrogen flame attachment and photomultiplier. Exchangeable H was estimated by the Woodruff buffer technique (17). The glass electrode was used to determine the pH of a soil paste. The particle size distribution was determined by the hydrometer method and carbonates were estimated by a volumetric measurement of evolved CO_2 at constant pressure from acid treated soil. Volume weight was determined on soil cores of measured volume at field moisture content.

Soils Studied

Four distinctly different soil situations were selected for study as follows:

1. An acid Thurman soil, sampled near Pierce, Nebr., was formed from outwash, sandy materials deposited over Peorian loess.
2. An acid Crete soil, developed from Peorian loess, was sampled at Agronomy Farm, Lincoln, Nebr. This soil has a high content of clay in the B horizon.
3. Judson soil, with little textural profile differentiation developed on acid colluvial material of loessial origin, was sampled at Agronomy Farm, Lincoln, Nebr.
4. Crofton soil, formed from highly calcareous Peorian loess which was extremely low in soluble phosphorus, was sampled near Decatur, Nebr.

One ton of lime per acre was used for liming plots on the Thurman soil. Four tons per acre were used for the Crete and Judson soils. The original pH of all soils was 5.3. Final values were 6.3, 5.7, and 6.3, respectively.

EXPERIMENTAL RESULTS

Alfalfa root systems were removed from limed and unlimed plots of Thurman soil, one, two and three growing seasons after seeding (see figure 1). The essential feature of this soil was the acid sandy material which covered, to a depth of 3 feet, loessial material more adequately supplied with calcium, magnesium, and phosphorus (see figure 1 and table 1). During the first growing season (April–October) alfalfa roots penetrated more than 5 feet into the limed soil. Root branches and nodules were most abundant in the 0 to 3 inch depth of this soil, and in the sand (27 to 32 inches) above the loessial material. There were no nodules and few fibrous roots between 3 and 27 inches. Soil material at this depth gave indications of calcium, magnesium, and phosphorus deficiencies.

In contrast to the rapid initial growth of roots of limed alfalfa, those of unlimed alfalfa reached a maximum depth of only 36 inches during the first growing season. No nodules were observed on these roots. Many of these stunted plants did not survive the first winter; however, those which remained made excellent growth during the second year (see figures 2–3) and root samples indicated that accelerated growth was accompanied by root penetration of the loess material which had an adequate supply of nutrients. After 2 years, extensive nodulation was found in the 12 to 24 inch zone, and after 3 years nodules were especially abundant at a depth of 24 to 36 inches. Plants growing in reduced stand on unlimed soil developed larger tap roots than did plants growing in more dense stands on limed soil.

Figure 4 gives the distribution of alfalfa roots from the Crofton soil. This soil was severely puddled in the surface 6 inches and many fibrous roots and nodules were lost in the washing process. Very low phosphorus availability was an outstanding feature of the Crofton profile although the relative amount varied greatly with depth as seen in figure 4. There was little branching and no nodule development between the depths 14 to 60 inches, a region of zero phosphorus availability as measured by soil test. Many fibrous roots and nodules were found above 14 inches and moderate branching with occasional nodules occurred below 60 inches.

Root systems of limed and unlimed sweetclover plants from the Crete soil are presented together with associated soil properties in figure 5 and table 2. Extensive root branching in the surface soil corresponds with the depth of plowing. A few nodules, brown and apparently dead, were found on roots growing near the surface of unlimed soils. Roots growing in the limed surface soil produced numerous small nodules. The acid soil material extending from 8 to 24 inches offered no physical barrier for root development. This was, however, a region of limited root branching. Sweetclover roots were much more branched in the subsoil high in clay below 24 inches, and nodules were found on limed and unlimed sweetclover below a depth of 42 inches.

Only isolated plants were available for sampling from unlimed Judson soil (see figure 6). The pattern of root

Table 1.—Particle size distribution of Thurman soil.

Depth (inches)	% Sand	% Silt	% Clay
0– 6	83	8	9
6–12	83	8	9
12–18	85	6	9
18–24	83	8	9
24–30	83	8	9
30–36	82	9	9
36–42	54	26	20
42–48	33	39	28
48–54	37	37	26
54–60	27	43	30

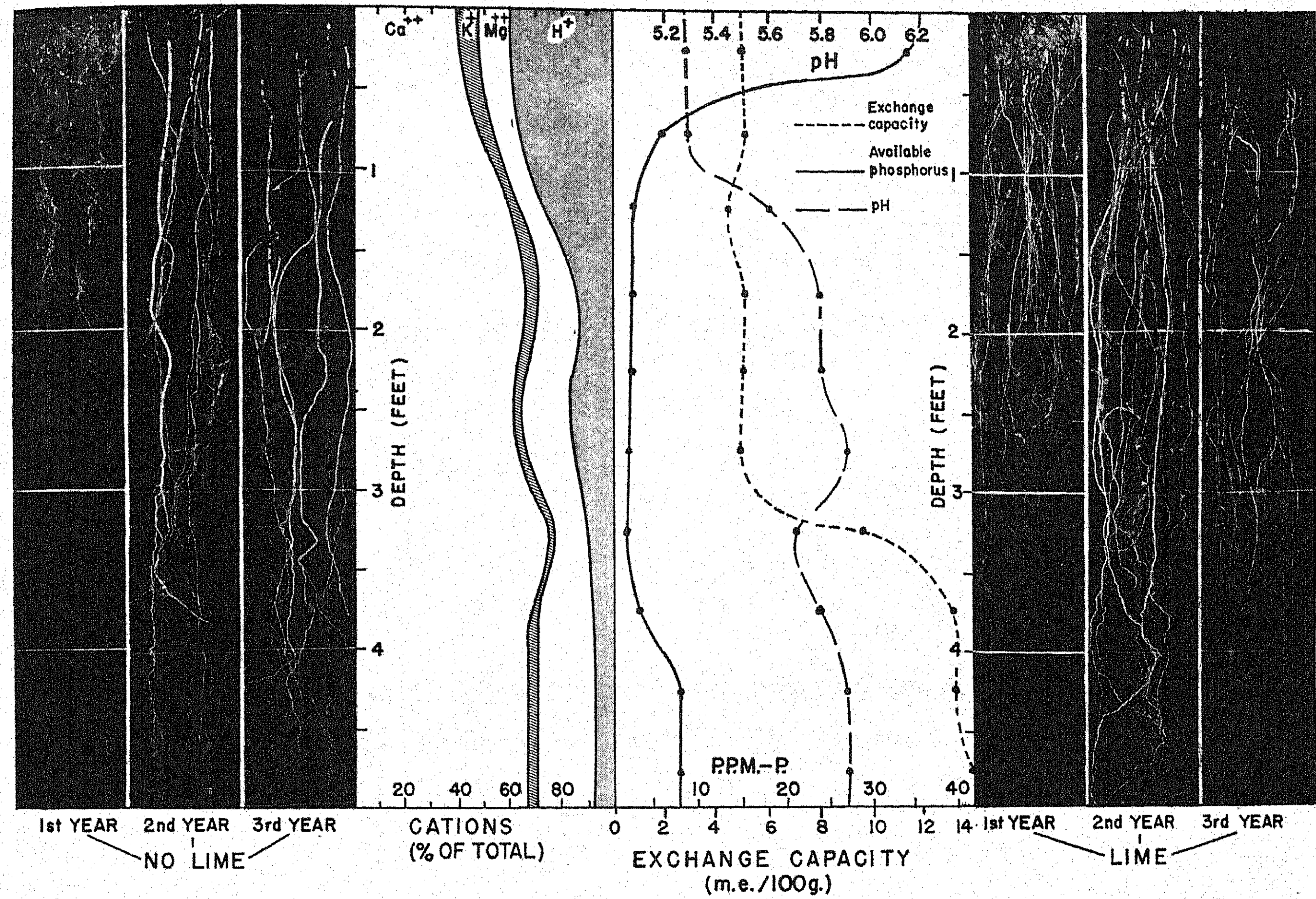

FIG. 1.—Root systems of alfalfa taken from a Thurman soil. Root samples are arranged according to soil treatment and year of sampling and are presented with some associated soil properties. Samples were taken in October of the years indicated. Roots growing on limed soil reached a depth greater than five feet during the first growing season. These roots cannot be distinctly seen in the photograph.

development was apparently related to burrowing by rodents. Limed soils produced plants well nodulated in the surface 6 inches. Below this depth there were scattered nodules. Root development decreased uniformly with depth.

DISCUSSION

The generally high requirement of alfalfa and sweetclover for nutrients make these plants well suited to a study of the influence of soil properties upon root development. The importance of various soil horizons for plant nutrition may be indicated by the nature and relative abundance of legume roots and nodules within the horizon. Variations in top growth as roots penetrate the various soil horizons may alsó be used as an indicator of the importance of these horizons in contributing plant nutrients (figure 2).

Phosphorus availability may influence root branching and nodulation. It is evident, however, that legume roots can exist at low levels of available phosphorus. Although no phosphorus was removed from much of the Crofton profile by the weak extractant employed, this soil is abundantly supplied with total and 0.1 N HCl soluble phosphorus. It is probable that the phosphorus level indicated by the soil test does not adequately represent the phosphorus available to the alfalfa plant since satisfactory yields of alfalfa were obtained from this soil without phosphorus fertilization.

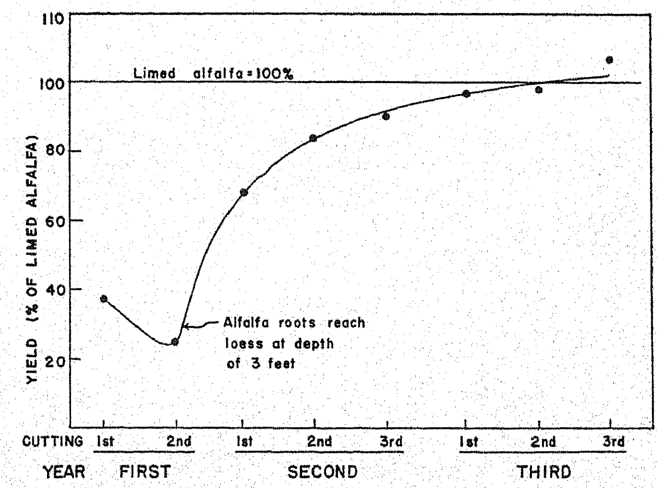

FIG. 2.—Yield from unlimed alfalfa plots, Thurman soil, as percent of the yield from limed plots for eight cuttings. The initial value for the unlimed plots is high because of grassy weeds.

Nodules developed on alfalfa roots growing in acid soil material (Thurman soil) when roots penetrated soil horizons more adequately supplied with calcium at a lower depth. These observations indicate that an upward trans-

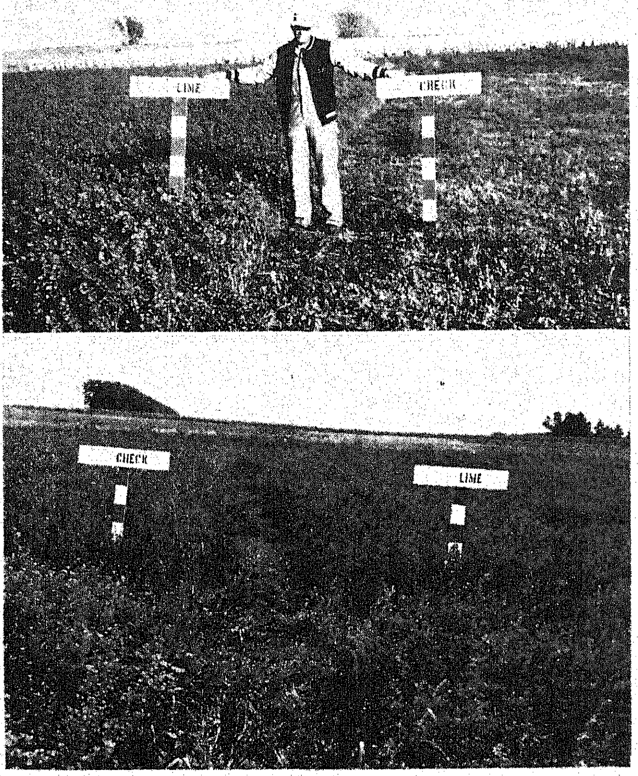

FIG. 3.—Alfalfa growth on Thurman soil as influenced by liming the surface soil (above) and by the availability of subsoil nutrients (below). Photographs were taken of different plots.
Above: Regrowth after second cutting, first year alfalfa, showing marked response to lime before roots of unlimed alfalfa were established in the loessial material below 3 feet.
Below: Second year, third cutting alfalfa after roots of unlimed alfalfa had penetrated loessial material.

Table 2.—Particle size distribution and volume weights of Crete and Judson soils.

Depth (inches)	Crete soil			Judson soil		
	% Silt	% Clay	Volume Weight	% Silt	% Clay	Volume Weight
0– 4	55	32	1.11	55	31	1.26
4– 8	55	34	1.08	55	31	1.22
8–12	51	36	1.22	53	33	1.24
12–16	50	37	1.27	55	34	1.28
16–20	52	37	1.20	56	35	1.29
20–24	50	41	1.30	52	37	1.30
24–28	40	48	1.36	54	37	1.32
28–32	40	48	1.41	53	37	1.33
32–36	42	48	1.48	55	36	1.35
36–40	42	46	1.56	52	37	1.36
40–44	44	44	1.54	53	36	1.34
44–48	47	43	1.47	56	34	1.31
48–52	46	42	1.52	55	34	1.37
52–56	48	41	1.51	58	32	1.36
56–60	48	41	1.55	57	32	1.33

location of calcium may influence nodule development. In this respect, calcium saturation does not seem to be particularly localized in its effect.

Heavy subsoils which have an adequate supply of nutrient cations may be more important for legume nutrition

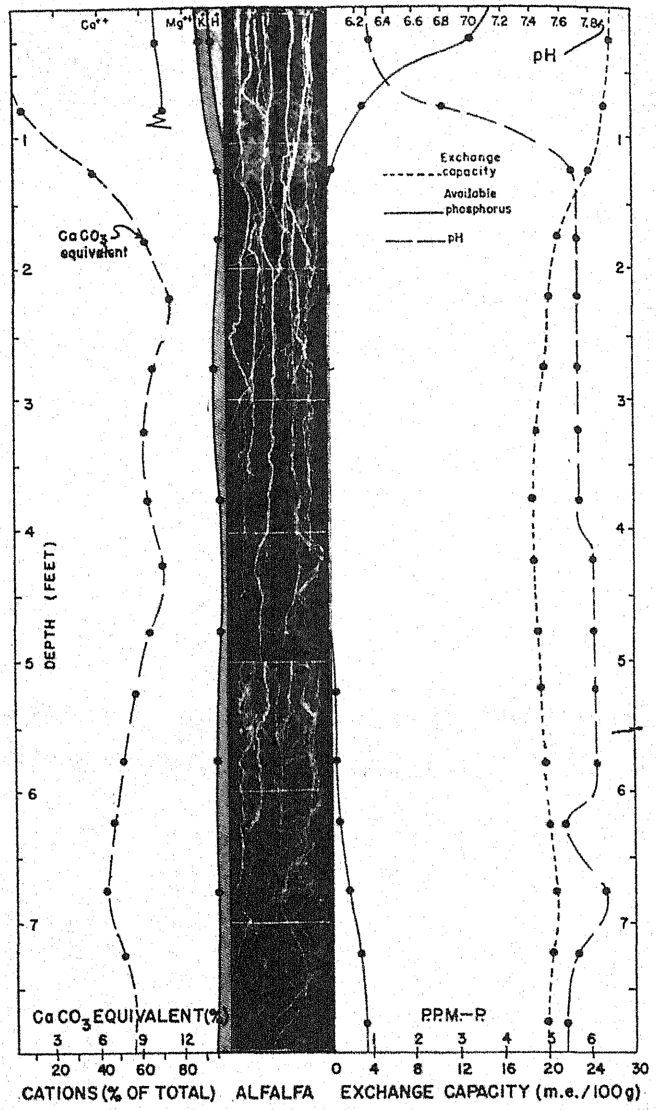

FIG. 4.—Roots of alfalfa taken from an 8 foot monolith of Crofton soil. The cations Ca^{++} + Mg^{++} as percentages were obtained by difference in the calcareous soil below 1 foot. Many fibrous roots and small nodules were lost from the puddled surface soil during the washing process.

than horizons nearer the surface which have more favorable physical properties but are less abundantly supplied with nutrients. Roots may be more fibrous and better nodulated in a heavy subsoil (Crete soil) than in the more favorable physical environment but less favorable chemical environment at a similar depth in another soil (Judson 2 to 3 feet).

The surface soil environment is but one set of conditions which influence a root system. Thus a study of soil-root relationships throughout the depth of root penetration has value for making lime and fertilizer recommendations. Examples of acid surface soils underlain at shallow depth with calcareous material (such as the Crofton soil) are not unusual. The wisdom of recommending lime for soils only on the basis of a surface sample may be questioned. Conversely, to withhold lime because of abundant calcium in the subsoil may be shortsighted. Better nodulation, improved stands and increased early yields resulted from

liming acid soils even when their subsoils were adequately supplied with calcium.

SUMMARY

A study was made of the influence of exchangeable calcium, available phosphorus, and soil texture in the profile of four Nebraska soils on root development and nodulation by alfalfa and sweetclover.

The development of alfalfa root systems growing on limed and unlimed acid soils was studied for 3 years. During the first season alfalfa roots penetrated more than 5 feet into the limed soil, while those of unlimed alfalfa reached a maximum depth of only 36 inches. Unlimed alfalfa was very unproductive during the first year but became progressively higher during the second and third years. Root samples indicated that accelerated growth was accompanied by root penetration of soil material below 3 feet which was better supplied with nutrients. Root and nodule development reflected the availability of soil nutrients in the various horizons.

Nodules and fibrous roots of alfalfa were abundant in a surface soil which contained a small amount of available

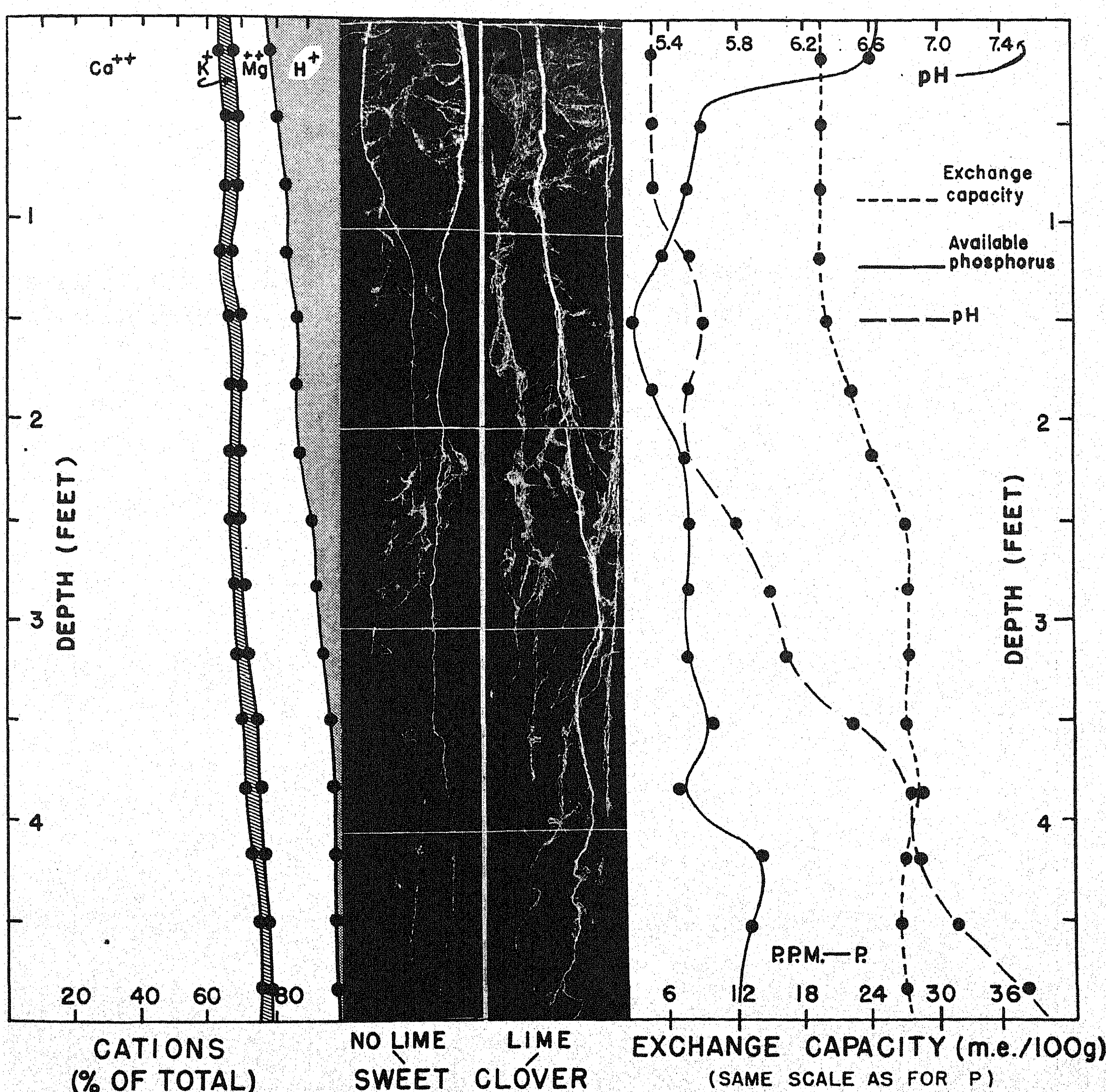

FIG. 5.—Roots of second year (May) sweetclover taken from a 5-foot monolith of Crete soil and some associated soil properties. Roots from the unlimed plots were not representative of the entire plot area.

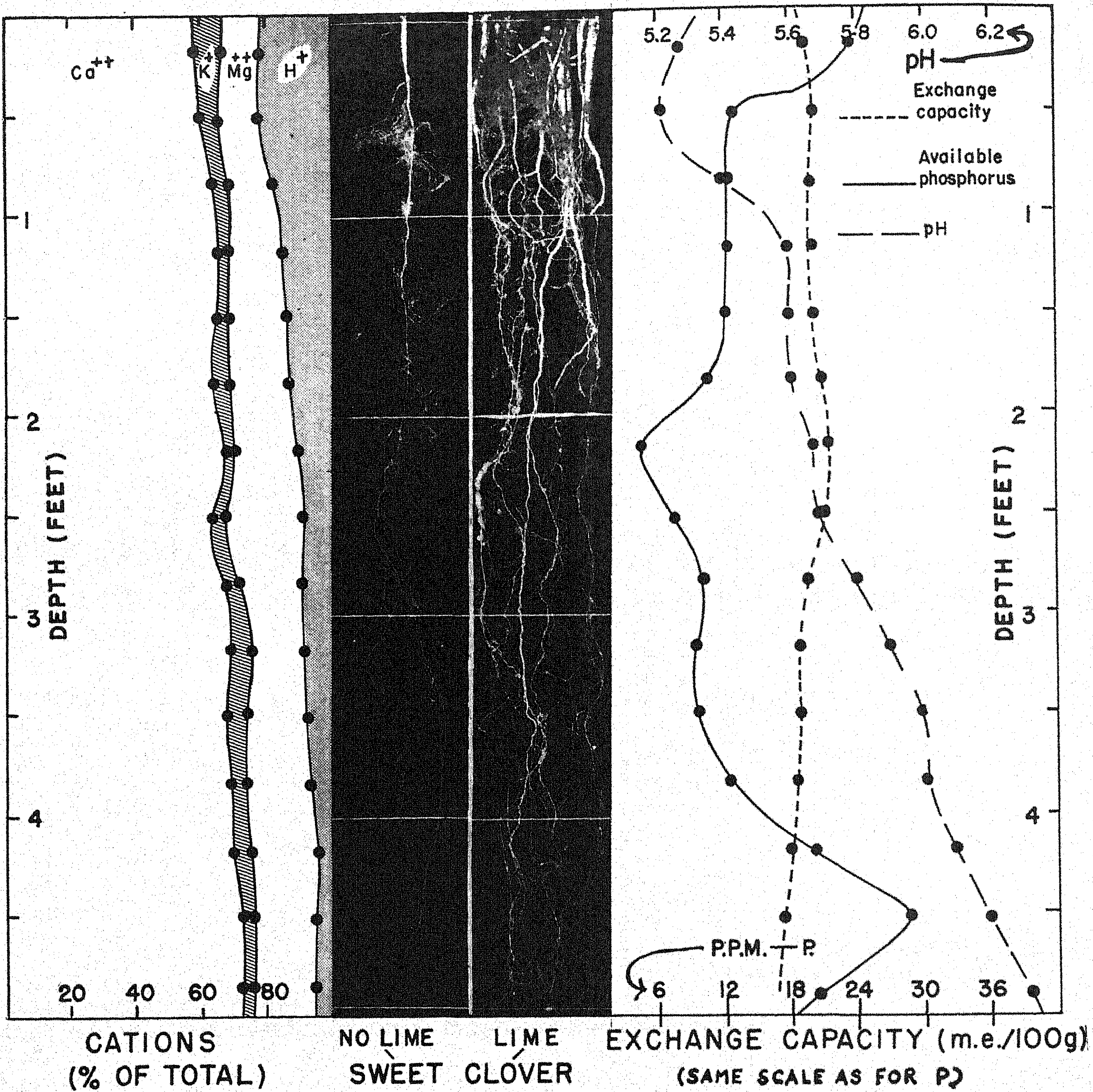

FIG. 6.—Roots of second year (May) sweetclover taken from a 5-foot monolith of Judson soil and some associated soil properties. Root system from the unlimed plot came from an isolated plant.

phosphorus. These were lacking in the calcareous subsoil where no available phosphorus could be detected.

Sweetclover roots were better developed and nodules more numerous in the clay subsoil of a Crete profile than in soil material nearer the surface. Roots and nodules were also better developed in the Crete clay subsoil than at a similar depth in a Judson soil. The Judson soil and upper horizons of the Crete soil gave evidence of a more favorable physical environment but the clay subsoil of the Crete profile was more adequately supplied with nutrient cations.

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Climatic Factors and Corn Yields in Texas Blacklands*[1]

R. P. Bates[2]

CORN yields on upland soils in the Blackland Prairie of Texas seldom exceed 60 bushels of grain per acre. Lack of moisture during the growing season is usually considered to be the limiting factor. Experiments conducted at the Temple Experiment Station, in which abundant moisture was applied by irrigation, have produced corn yields of about 90 bushels per acre. In such experiments fertilizer applications, plant populations, and cropping systems have been varied in an effort to eliminate these as limiting factors. These results indicate that climatic factors such as temperature, humidity, frequency of rains, number of cloudy days, and number of hot winds are limiting corn yields in addition to total amount of seasonal rainfall. To gain more knowledge of the factors involved, a study was made of relationships between several climatic factors and corn yields.

REVIEW OF LITERATURE

Several reports have been published concerning effects of climatic factors on corn. In most cases rainfall and temperature effects on inbred lines of corn were studied. Jenkins (3), Lonnquist and Jugenheimer (5), and Heyne and Brunson (2) reported effects of high temperatures and drought on growth and seed-set of inbred lines. Tatum and Kehr (7) found a very close relationship between seed-set and temperatures and humidities at pollination time. They suggested that temperature and humidity influence pollination indirectly through their effects on evaporation and transpiration. Basile (1) reports that drought periods in the northwest corner of the corn belt definitely reduce yields for years of drought, and in some cases even for the following year.

Time of year where shortage of moisture appears to do greatest damage is during the pollination period. Robins and Domingo (6) found that if plants were allowed to wilt for 1 or 2 days during this period, corn yields were reduced as much as 22%, and if wilting continued for 6 to 8 days, yield reductions of as much as 50% resulted. Yield reductions were related to maturity of grain at the time wilting occurred.

Kiesselbach (4) found highly significant correlations between corn yields in Nebraska and the following factors: mean temperature during June, July, and August; annual precipitation; precipitation during June, July, and August; seasonal evaporation; mean seasonal relative humidity; as well as several other factors. Evaporation, temperature, and humidity gave the highest correlations with yields.

MATERIALS AND METHODS

Data on climatic conditions and corn yields were taken from records of Texas Substation No. 5 at Temple. Records were available for the 41-year period from 1913 through 1953, with a few exceptions where data for the first 2 or 3 years were not available. Climatic factors studied were rainfall during several periods of each year, mean maximum June temperature, number of rains in June, mean relative humidity in June, evaporation in June, number of cloudy days in June, and number of hot winds in June. Since corn grown in this area is pollinated during June, most of the climatic variables for this month are of possible interest.

Yields used in this study were obtained from annual reports. A mean yield was secured for each year by averaging yields of the ten highest yielding varieties or hybrids in the variety test each year. The top 10 varieties were used instead of all varieties because number of entries varied during the 41-year period, and higher yielding varieties and hybrids were tested for longer periods of time while the lower yielding ones were discarded after a year or two of testing. Since the lower-yielding entries were excluded from the calculations, results of these correlations might be buffered against extremes, especially in years with extremely unfavorable climatic conditions. No doubt some variation existed from year to year due to previous crops, fertilizer treatments, and improved varieties and hybrids of corn. In most years, experiments were conducted with fertilizer treatments and cropping systems. In such cases three or four of the highest yields from these experiments were included in obtaining the yearly mean. The development of corn hybrids might have resulted in higher yields during the last 15 years; however, according to the records, some of the highest yields were produced before hybrids were introduced. Perhaps decline in soil productivity has to some extent counteracted the

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[1] Contribution from Texas Agr. Exp. Sta. Substation No. 5, Temple, Tex. This work was cooperative with the Soil and Water Conservation Research Branch, Agricultural Research Service, USDA. Received March 12, 1955.

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Table 1.—Relationships between several climatic factors and corn yields at Temple, Tex., 1913–53.

Climatic factor or factors correlated with yield	Degrees of freedom	Correlation coefficient	Coefficient of determination*
Mean maximum June temperature	39	−0.7922**	62.8
Evaporation in June	37	− .7920**	62.7
Mean relative humidity in June	37	.7906**	62.5
Number June rains	37	.6438**	41.4
Total June rainfall	39	.5506**	30.3
Total rainfall from Oct. 1 to Aug. 1	38	.5477**	30.0
Number cloudy days in June	37	.4656**	21.7
Number hot winds in June	34	− .0057	——
Mean maximum temperature and mean relative humidity in June	37	.8433**	71.0
Mean relative humidity and evaporation in June	37	.8359**	69.9
Mean maximum temperature and evaporation in June	37	.8257**	68.2
Mean maximum temperature and total rainfall in June	39	.7989**	63.8

* Coefficient of determination is obtained by squaring the r or R value and multiplying by 100. The value indicates the percentage of variation in yield accounted for by variation in the other factor or factors involved in the correlation coefficient.
** Indicates that r and R value equals or exceeds that required for a probability of 0.01.

effect of corn hybrids. Since the top-yielding varieties, fertilizer treatments, and cropping systems were used in obtaining the mean yields, they are higher than average corn yields under general farm conditions. They should serve, however, to show the effects of various climatic factors over a period of years.

RESULTS

During the 41-year period, yields ranged from 4.2 to 57.4 bushels per acre. Mean maximum June temperatures ranged from 86.0 to 99.9 degrees Fahrenheit, while mean relative humidity varied from 53.7 to 81.7%. June rainfall varied from 0.08 to 8.72 inches, and total rainfall from Oct. 1 to Aug. 1 varied from 9.53 to 50.66 inches. Number of June rains ranged from 1 to 14.

Table 1 shows that all factors studied are associated with yield except the number of hot winds. Mean maximum June temperature gave the highest correlation coefficient among the single factors. Mean relative humidity and evaporation also showed a high degree of correlation with yield. The number of rains in June showed a higher correlation with yield than did either total June rainfall or total rainfall from Oct. 1 to Aug. 1. Number of cloudy days in June did not show a high association with yield. Multiple correlation coefficients calculated among pairs of climatic factors and yield indicate that over 70% of yield variation was attributable to the mean maximum June temperature and mean relative humidity in June.

Rainfall data at Temple indicate that distribution of moisture during the growing season is more important in corn production than the total amount of moisture during the season. In data given thus far, only rainfall in June and rainfall from Oct. 1 to Aug. 1 were mentioned. These two periods gave the highest correlation coefficients among several periods. When either May or July rainfall was added to June rainfall, the correlation coefficient was reduced. Rainfall during all the periods studied was significantly correlated with corn yields except for the period from Sept. 1 to March 1. This period was included to determine if pre-planting moisture alone was related to yields.

Mean maximum temperatures obtained for weekly periods in June and July did not give as high a correlation coefficient in any week as did the mean for the whole month of June. Table 2 shows, however, that correlation coefficients increased during the third and fourth weeks in June and then declined very rapidly in the first and second weeks of July. Since most of the corn in the Temple area is pollinated about, or just prior, to the middle of June, the pollination period and the filling-out stage immediately following pollination appear to be the most critical stages with respect to high temperatures.

Table 2.—Correlations between weekly mean maximum temperatures and corn yields at Temple, Tex., 1913–53.

Weekly period	Degrees of freedom	Correlation coefficient	Coefficient of determination
June 1–7	38	−0.3894*	15.2
June 8–15	38	− .5229**	27.3
June 16–23	38	− .7002**	49.0
June 24–30	38	− .7303**	53.3
July 1–7	38	− .4290**	18.4
July 8–15	38	− .0871	0.8

Table 3 shows that close relationships existed between mean maximum June temperature, mean relative June humidity, and mean June evaporation. Rainfall was not as closely correlated with mean relative humidity as was mean maximum temperature. Number of rains in June was not correlated as closely with relative humidity as was total rainfall in June. This was surprising since the number of June rains was correlated more closely with corn yields than was total June rainfall.

DISCUSSION

Even though total rainfall from Oct. 1 to Aug. 1 was not as closely correlated with corn yields as was relative humidity, rainfall apparently accounted for more yield variation in years of extremely low rainfall. If seasons with less than 22 inches of rain between Oct. 1 and Aug. 1 were excluded, the correlation coefficient indicated that there was no correlation between rainfall and corn yields. The results obtained indicate that total rainfall from Oct. 1 to Aug. 1 has a pronounced effect on corn yield up to a certain level. After this level is reached, such factors as temperature, humidity, and distribution of rains have more effect. In the case of June temperature and humidity a higher correlation was shown with extremely high temperatures and low humidities; however, some correlation was shown with the lower temperatures and higher humidities.

Table 3.—Relationships among several climatic factors at Temple, Tex., 1913–53.

Factors correlated	Degrees of freedom	Correlation coefficient	Coefficient of determination
With mean maximum June temperature:			
June rainfall	39	−0.5848**	34.2
Rainfall from Oct. 1 to Aug. 1	38	− .4598**	21.1
Mean relative humidity in June	37	− .7616**	58.0
Evaporation in June	37	.8136**	66.2
Relative humidity and evaporation in June	37	.8559**	73.3
With mean relative humidity in June:			
Evaporation in June	37	− .7920**	62.7
June rainfall	37	.5966**	35.6
Number of rains in June	37	.3489*	12.2

The correlations with temperature were negative while those with humidity were positive.

Temperature and humidity are probably acting as one factor in affecting transpiration from corn leaves, evaporation and drying of silks, desiccation of pollen grains, and prevention of fully-developed corn grains. If there is a shortage of moisture, the plant and yield will be damaged from these causes. With available moisture in the root zone, however, the plant might still suffer if temperature and humidity are such that evaporation and transpiration rates exceed absorption and translocation rates. The amount of damage might be affected to some extent by the hybrid being grown, since there is some evidence that inbred lines of corn differ in freedom of water movement in the plants and in their ability to resist heat and drought. In some cases soil conditions might affect the amount of damage by affecting root extension and availability of moisture.

Perhaps the best way to avoid the worst effects of high temperature and low humidity is to advance the pollination period far enough into May so as to escape these adverse conditions. Usually temperature and humidity are much more favorable during the last weeks of May and first week of June. In most years, a 2-week earlier pollination period would escape most of the unfavorable conditions. This earlier pollination period might be accomplished by earlier planting; however, most of the corn in this area is already planted as early as possible and still escape cold injury. This difficulty might be overcome to some extent by developing corn hybrids that are more tolerant to cold, moist soils during germination and in the seedling stage. Such hybrids might be planted a week or two earlier. Another possibility for advancing the pollination period is by planting earlier-maturing hybrids. Some hybrids already have bene developed that are as much as 1 week earlier than the commonly-grown hybrids. Since inbred lines are known to have differential responses to heat and drought, it should be possible to develop hybrids better able to withstand these extreme climatic conditions.

Another possible way to reduce effects of high temperature and low humidity is to improve soil conditions so that more moisture may be stored in the soil, since abundant available soil moisture will reduce damage from high transpiration rates. Improved soil conditions would no doubt increase development and distribution of roots. This should tend to increase absorption rates and minimize the effects of high temperatures and low humidities.

SUMMARY

To obtain a better understanding of climatic factors limiting corn yields, correlation coefficients were calculated between several climatic factors and corn yields during a 41-year period from 1913 through 1953.

Mean maximum temperature, mean relative humidity, and evaporation in June (the month in which corn is usually pollinated) were very closely correlated with corn yields. These three factors were closely correlated with each other, and since evaporation is dependent on temperature and humidity, the latter two factors appear to be those affecting corn yields. Each of these factors was more closely correlated with corn yields than was rainfall at any period of the year. The number of rains in June showed a higher correlation with yield than did any other rainfall factor. Rainfall in June was correlated more closely with yields than total rainfall during any other period. If rainfall during more than 1 month was considered, the period from Oct. 1 to Aug. 1 showed the highest correlation with yields. Number of cloudy days in June was not closely correlated with corn yields and the correlation which existed was probably due to effects of rainfall, humidity, and temperature.

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Evaluation of Combining Ability in *Dactylis glomerata* L. III. General and Specific Effects[1]

R. R. Kalton and R. C. Leffel[2]

CURRENT concepts regarding general and specific combining ability and their significance in crop breeding have evolved primarily through fundamental investigations with corn. Extensive results show that combinations of inbred lines proven high first in general and then in specific combining ability are successful in production of superior hybrids. In most cross-pollinated forage crops, on the other hand, the ultimate breeding objective is a superior synthetic variety with persistent advanced generation performance. Most studies in forage breeding up to now have centered on evaluations of general combining ability. Little is known regarding specific crossing effects and their potential importance in the development and performance of synthetic varieties. This report represents an attempt to provide additional information on the latter point by analyses and interpretation of data obtained from a test of all possible single crosses among 11 clones of orchardgrass, *Dactylis glomerata* L.

REVIEW OF LITERATURE

Sprague and Tatum (10) defined general combining ability as the average performance of a line in hybrid combinations, attributable largely to additive genetic effects. Instances where certain crosses performed above or below expectations based on average performance of the lines involved were designated as specific combining ability. Dominance and epistatic effects of genes were considered as possible contributors to such performance. In single cross tests of lines previously selected for test cross merit, they found that variance was generally greater for specific than for general combining ability. Converse results were obtained in single cross tests of lines unselected for combining ability.

Rojas[3] developed mathematical models and formulae for determining variances of general and specific combining ability and their interaction with years and locations for a group of experiments involving all possible single crosses among *n* inbred lines of corn. In a subsequent publication, Rojas and Sprague (9) analysed 15 such single cross tests, 13 of which showed a greater variance for specific than for general combining ability. Interactions of general combining ability with years and locations were consistently smaller than those for specific combining ability, indicating that information on the latter will often be lower in predictive value than information on average test cross performance. They interpreted their results to mean that variance for specific combining ability was strongly affected by genotype-environmental interactions as well as by dominance and epistatic effects.

Several reviews pertaining to evaluation of combining ability in forage crops are available (3, 5, 7). Some studies are cited where differences in single cross performance were obtained in several grasses and legumes. In one instance Bolton (1) evaluated all possible single crosses among 13 inbred and among 13 non-inbred alfalfa clones for forage and seed yield and found differences in specific combining ability. He discussed possibilities of using only a few testers for evaluating combining ability of selections rather than having to make and evaluate all possible single crosses. Knowles (7) isolated general and specific combining ability variances in diallel crosses among one group of seven bromegrass clones, and three groups of nine, seven, and seven crested wheatgrass clones. Average variance was about 10 times greater for specific than for general combining ability in the bromegrass test. Presence of variable numbers of inbred plants in the progenies was thought to have influenced the results. Specific combining ability of a plant for forage yield showed little relationship to average or general combining ability performance in crosses. In all three wheatgrass tests the average variance was greater for general than for specific combining ability, and clones high in yield in specific crosses also were high in average single cross performance.

Johnson (3) emphasized the need for additional information on the relationships among general and specific combining ability evaluations and synthetic variety performance in forages. In a study of relationship between number of parental lines and theoretical performance of synthetic varieties of corn, Kinman and Sprague (6) found that F_2 yields of all possible single crosses among 10 inbreds were closer to arithmetic than to geometric expectations. Depending on the nature of gene action, theoretical calculations showed four to six lines to be the most suitable number for recombination into a synthetic on the basis of results in their study. They pointed out that higher yielding synthetics probably could be obtained from recombining high combining S_1 rather than advanced generation inbred lines. Lonnquist (8) summarized available information on synthetics in corn. He noted that most showed no superiority over open-pollinated varieties with the exception of one produced by recombining eight high combining inbreds at the Minnesota Station. In his own studies, a synthetic of eight S_1 lines high in topcross performance exceeded the parental variety, Krug, in yield in both Syn-2 and Syn-3 generations. Of particular interest to forage breeding was the deduction that S_1 lines proven high in general combining ability offered greater promise for developing high yielding synthetics than long-time inbreds where specific combining ability effects assumed greater significance.

Research on synthetic varieties in forages has been most extensive with alfalfa. Graumann (2) reviewed this work pointing out that selection of lines to incorporate into synthetics was based on polycross and other types of outcross progeny performance. A number of synthetics outyielded open-pollinated check varieties, with 2-clone generally better than multiclone combinations in Syn-1. However, rate of decline in yield in Syn-2 and Syn-3 appeared inversely proportional to number of parental clones. Six orchardgrass recombinations of 4 to 10 clones similar in general combining ability were studied by Weiss, *et al.* (11). No effect of parental clone number either on average agronomic merit or change in performance from Syn-1 to Syn-2 was observed. Also, no decline in vigor, disease resistance, or leafiness from Syn-1 to Syn-2 was noted even for the 4-clone synthetic.

In a sweetclover study, Johnson and Hoover (4) compared mean polycross (Syn-1) performance of four groups of S_1 lines selected for high, medium high, medium low, and low general combining ability on the basis of an S_0 open-pollination progeny test. Mean Syn-1 yields were 132, 115, 125 and 87%, respectively, of the parental variety, Madrid, thus indicating a positive relationship between general combining ability and synthetic performance.

MATERIALS AND METHODS

The S_0 clones used to produce the single cross progenies for this study were selected from long-time stands in Iowa on the basis of phenotypic desirability. Though representing a range in clonal performance, they were essentially unselected for combining ability. Single cross seed was produced in 1949 in paired plantings of all possible combinations among the 11 clones by mutual pollination under parchment bags. Progenies of the 55 crosses were established in August 1949 in 4 by 5 foot broadcast plots, each of which was

[1] Contribution from the Agronomy Department, Iowa Agr. Exp. Sta., Ames, Iowa. Journal Paper No. J-2729, Project 1178. Received March 18, 1955. The authors are grateful to Dr. M. G. Weiss for valuable assistance in the planning of this investigation.

[2] Associate Professor of Farm Crops and formerly, Graduate Assistant in Farm Crops, now Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A., College Park, Md., respectively.

[3] Rojas, B. A. Analysis of a group of experiments on combining ability in corn. M.S. Thesis. Iowa State College, 1951.

Table 1.—Analyses of variance of green forage yields and bloom dates of diallel crosses among 11 S_0 clones of orchardgrass in 1951, together with mean square expectations.

Source of variation	D.F.	Mean squares		Expectation of mean square
		Forage yield	Bloom date	
Replications	2	19.28**	10.85	
Single crosses	54	0.76**	18.30**	
Among clones	10	1.99**	78.53**	$S^2_E + rs^2_s + r(t-2)s^2_g$
Within clones among testers	44	0.48	4.61	$S^2_E + rs^2_s$
Replications × single crosses	108	0.35	5.10	S^2_E

** $P < 0.01$;

surrounded by a small border of timothy. A number of single crosses involving eight additional clones together with polycross and topcross progenies of all parents were included in the same test. The planting arrangement was a randomized block with three replications. A general discussion of previous clonal history and of outcross progeny performance for all entries in this test is presented elsewhere (5).

Progenies were evaluated for five different characters. Early spring vigor and leaf disease intensity were scored on a relative basis of *(1)* least to *(10)* most. Date of bloom was recorded as the calendar date when 50% or more of the panicles in a plot were shedding pollen. Panicle number was determined by actual count of a 2-foot square area in the center of each plot, while forage yield on a green weight basis was measured for a center 3- by 5-foot section. Data on the first three traits were obtained only in 1951. Panicle number and forage yield (two cuttings per year) were measured in both 1951 and 1952. Analyses of variance of all data were made using procedures outlined by Rojas.[1]

EXPERIMENTAL RESULTS

Analyses of variance typical of those used herein are presented in table 1 for forage yield and bloom date in 1951, together with appropriate mean square expectations. Mean differences among single crosses were highly significant ($P < 0.01$) for all traits except spring vigor where the F value only exceeded the 5% level. Of greater interest, however, were the results of partitioning the mean squares for single crosses. Variability in mean performance of each clone crossed with the other 10 provided an estimate of general combining ability variance (among clone variance) and all proved highly significant ($P < 0.01$). The residual variance (within clones among testers) represents the pooled variation of particular crosses involving each clone from the clonal average and is a measure of specific combining ability effect. This variance was statistically significant in only one of nine analyses—that for disease score.

The interaction of single crosses with years is another part of the analyses meriting consideration. The general combining ability × years interaction was significant at the 5% and 1% levels for forage yield and panicle number, respectively. In neither case was the specific combining ability × years interaction significant. Additional information was obtained by isolating the interaction variance components on the basis of mean square expectations as follows:

Mean square
years × among clones $= s^2_E + rs^2_{sy} + r(t-2)\, s^2_{gy}$

Mean square
years × within clones among testers $= s^2_E + rs^2_{sy}$

[1] *Op. cit.*

Table 2.—Variance ratios based on general and specific combining ability components from the analyses of variance.

Characteristic	Variance ratios (%)		
	G_A	G_S	G_E
Spring vigor score	15.1	5.5	79.4
Disease score	37.6	23.4	39.0
Bloom date	52.6	−1.5	48.9
Panicle number:			
1951	28.7	1.9	69.4
1952	36.5	−2.4	65.9
1951–52	42.3	1.8	55.9
Green forage yield:			
1951	23.5	7.8	68.6
1952	15.4	7.7	76.9
1951–52	21.1	9.2	69.7

where s^2_E is the mean square for years × single crosses × replications, *r* is replication number, and *t* is clone (tester) number. Resulting variance components were as follows:

	Panicle number	Forage Yield
s^2_{gy}	77.69	0.015
s^2_{sy}	−54.12	0.013

These values further indicate that the interannual inconsistency in performance for general combining ability in this test tended to be greater than for specific combining ability, particularly for panicle number. This is contrary to similar comparisons in corn (9).

Variance components from the analyses were utilized in another way to interpret the nature and extent of general and specific combining ability effects. For this purpose, Rojas and Sprague (8) suggested the following formulae:

$$G_A = \frac{2s^2_g}{T} \times 100;\ G_S = \frac{s^2_s}{T} \times 100;\ \text{and}\ G_E = \frac{s^2_E}{T} \times 100$$

where $T = 2s^2_g + s^2_s + s^2_E$.

Additive genetic effect or heritability in the narrow sense is estimated by G_A, while G_S estimates non-additive or specific combining ability effects. G_E is the environmental component or proportion. Variance ratios obtained by use of these formulae are given in table 2. Spring vigor score and forage yield, which were significantly correlated in this study, both were relatively low in percentage of additive genetic variance and influenced to a great extent by experimental error. Variance ratios for general combining ability

Table 3.—Two-year means for single cross combinations of parental clones classified as high or low in general combining ability on basis of polycross and topcross progeny performance.

Character	Progeny test used for classification	High × High 3 crosses	High × Low 9 crosses	Low × Low 3 crosses
Panicle no.	Polycross	82.6	53.8	23.4
	Topcross	79.7	50.2	26.1
Forage yield (lbs.)	Polycross	5.07	4.86	4.19
	Topcross	4.99	4.74	4.24

for these traits were about two to three times greater than for specific combining ability. Heritability for panicle number was about twice that for forage yield, though environmental effects were still relatively large. The highest percentage for G_A was obtained for bloom date, while leaf disease intensity expressed effects of both general and specific combining ability. Generally, these results signify that specific combining ability is of considerably less importance than general combining ability in this material, and that additional replication and better experimental control are needed to reduce environmental influences on mean performance.

Each clone involved in the diallel crosses also was represented by duplicate polycross entries and a topcross entry in the same test. In order to relate general combining ability to specific cross performance, the top three and the bottom three clones were selected on the basis of polycross and topcross progeny performance for panicle number and forage yield. Two-year means for the appropriate single cross combinations of high by high, high by low, and low by low are found in table 3. These data show that clones high or low in general combining ability also produced crosses *inter se* which were high or low, respectively, in mean yield and panicle number. Crosses between high and low combining clones were almost intermediate in average performance for panicle number which is suggestive of strong additive genetic effect. Mean yields of the high by low crosses approached closer to the high by high groups, indicating some non-additive or dominance influences.

DISCUSSION

Considering all results presented herein on agronomic performance of the 55 single crosses, it is evident that appreciable differences in general combining ability exist among the parental clones. Effects attributable to specific combining ability generally were either much lower in magnitude or not apparent, except in the case of disease score. Since the parental clones were essentially unselected for combining ability, such results might have been expected considering findings in corn (10).

Failure to find significant expressions of specific combining ability for all traits but one in this study may have been due to several factors. Lack of sufficient replication and resultant high experimental errors very probably was one of the potent reasons. The genetic nature of the parental material may have been another. All clones were non-inbred and presumably highly heterozygous. Thus, single cross progenies would be comparable to those of double crosses or crosses of two S_0 plants in corn from a genetic standpoint. Under such conditions, it is highly probable that decidedly superior or inferior combinations would have little chance of occurrence or expression in any progeny consisting of a mixture of many genotypes. This would be especially plausible when considering highly polygenic characters. If this latter explanation holds, evaluation for specific combining ability in non-inbred or even S_1 material in a breeding program with cross-pollinated forage crops would hardly prove worthwhile. Realistically, it also should be pointed out that single cross testing is recognized to have decided limitations with most such crops because of the difficulties and expense of pollination control.

Another factor to consider is the relationship between combining ability and synthetic variety performance (3, 8). In corn and alfalfa, selection for high general combining ability has led to production of high yielding synthetics. Selection for high specific combining ability, on the other hand, may give a high yielding synthetic in Syn-1, but dissipation of non-additive genetic effects may lead to unwanted declines in performance in Syn-2, Syn-3, etc. Much more information is needed in this area of forage breeding to determine the correctness of these interpretations. Meanwhile, on the basis of practical and genetic evidence at hand, selection for high general combining ability appears more worthy of attention and more promising than selection for high specific combining ability if the ultimate goal is a superior synthetic variety. Increased study of the significance of progeny × year and progeny × location interactions in such evaluations also seems merited, judging from the results obtained herein.

SUMMARY

All possible single crosses among 11 non-inbred clones of orchardgrass were evaluated for early spring vigor, leaf disease reaction, and bloom date in 1 year and for panicle production per unit area and forage yield over a 2-year period. Variances attributable to general combining ability were greater than for specific combining ability in all comparisons. Disease score was the only trait exhibiting significant specific combining ability. Expression of general combining ability differences among clones was inconsistent over the 2 years as indicated by significant among clones × years variances for both yield and panicle number. Application of the results to evaluation of combining ability in breeding of cross-pollinated forage crops was discussed, together with implications pertaining to development of synthetic varieties.

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Variability and Inheritance of Reaction of Barley to Race 15B of Stem Rust[1]

John D. Miller and J. W. Lambert[2]

ALTHOUGH yield reductions in barley due to black stem rust, *Puccinia graminis*, Eriks., and Henn. have not averaged very high in the past, there are, nevertheless, several reasons why additional research is needed on this disease. Losses in certain years have amounted to 10 or 15% for entire states or the United States as a whole. Moreover, the sudden increase in prevalence of race 15B has made it desirable to determine sources of resistance to it and the mode of inheritance of this resistance as well as the degree of correlation of reactions of barley varieties at various stages of growth under different environmental conditions. This paper reports such studies.

REVIEW OF LITERATURE

Black stem rust has been studied much more intensively in wheat than in barley because of the greater economic losses in wheat yield and quality. Several reviews have been prepared which summarize the information on resistance of wheat to black stem rust (1, 4, 10). Others have reviewed the literature on the effect of environmental factors on stem rust reaction[3] (2, 4). Hart has considered the nature of resistance of wheat to stem rust (3).

Smith (6) reviewed the literature on inheritance of stem rust reaction in barley. In most cases investigators report resistance to be governed by a simple dominant gene that was located originally in Chevron, C.I. 1111 and Peatland C.I. 5267, which are sister selections. Andrews[4] also found one factor governing resistance. Smith (6) reviewed the literature on the relationship between the reaction of barley to stem rust at various stages of growth. Most investigations have found a close relationship between reactions of seedlings and adults particularly to the same race of stem rust.

Patterson[5] reported a study of stem rust on barley using 69 varieties and additional segregating material tested with races 17, 19, and 56 of stem rust. He found resistance to be conditioned by a single major factor plus one or more modifying factors in a cross of Valentine × Rabat, C.I. 4979. In a cross of Hietpas 5 × Chevron, he obtained in F_2 a 15:1 ratio of resistant to susceptible plants.

Patterson[5] also reported work on the effect of temperature on seedling reactions, using 69 varieties at temperatures of 16°, 20°, 24°, and 28° C. and using races 17, 19, and 56 of stem rust. He found 28° C. to be the temperature at which best differentiation would be made between varieties resistant and susceptible in the field. A good agreement was found between seedling and adult plant reaction to the same race of rust.

Race 15B has been reported by several investigators to have several biotypes[6, 7] (4, 5, 7, 8). These biotypes can be differentiated by means of their reaction on certain varieties of wheat in addition to the usual twelve differential varieties.

MATERIALS AND METHODS

All barley varieties studied had the spring growth habit. Many of them were in rod row tests at St. Paul and other stations in Minnesota in 1951 and 1952. However, the largest group came from the World Collection of barleys of the United States Department of Agriculture and were obtained originally from many sources both foreign and domestic. Seed of these varieties was provided by Dr. G. A. Wiebe of the Field Crops Research Branch, Agricultural Research Service of the United States Department of Agriculture.

This research was initiated in the field in the summer of 1951 when 1,042 varieties from the World Collection and about 140 varieties from rod row tests were inoculated with a mixture of races 15B, 17, 19, 38, 56, and 59A of stem rust.[8]

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[7] Shukla, *op. cit.*

[8] The writers are indebted to the Federal Rust Laboratory, St. Paul, Minn., for supplying all races of stem rust used in these studies.

Resistant strains isolated from the World Collection in 1951 and the entire group of varieties in rod row tests were studied as seedlings at low (70°F.) and high (82°F.) temperatures for reaction to race 15B during the fall and winter of 1951–1952. During this period about 80 of the varieties selected as resistant, intermediate, or susceptible on the basis of seedling tests were studied as adults at high and low temperatures. The entire group of about 290 varieties was grown in a field nursery inoculated with 10 collections of race 15B during the summer of 1952.

Seedlings of two crosses, Minnesota 615 × Kindred, and Minnesota 615 × Montcalm, were studied in the F_1 and F_3 generation at high and low temperatures during the winter of 1951–52. A few F_1 plants were tested also as adults at low temperature during this period. In the summer of 1952 the F_1, F_2, and F_3 generations of these 2 crosses were grown to maturity along with the 290 varieties in the 15B field nursery described above.

For the seedling tests, approximately 25 seeds were planted per 4-inch pot. About 7 or 8 days after planting, these seedlings were sprayed with water and rubbed to remove the waxy bloom after which they were again sprayed. A mixture of urediospores and talc was applied from a glass cyclone chamber (9). Following inoculation, the plants were again sprayed with a fine mist of water and covered with a moist cloth or tarpaulin for approximately 36 hours at about 70°F. After this, the plants were uncovered and spaced widely on greenhouse benches. Supplemental light was provided from 11:00 p.m. to 8:00 a.m. A recording thermograph showed that air temperatures were maintained about as planned.

Field plots were single 6-foot rows spaced 1 foot apart. In the alleys and around the outside border, spreader rows of susceptible barley varieties were planted. The V-belt planter was used for varieties and F_3 lines. F_1's and F_2's were planted by hand 5 and 3 inches apart, respectively. The spreader rows were inoculated at 3- or 4-day intervals with an aqueous spore suspension injected hypodermically at the preboot or boot stage.

A modification of the conventional method of scoring pustule type in wheat seedlings was necessary in the present study. Chlorosis is apparently more common in barley than in wheat, and the typical class 2 or "green island" reaction that occurs in wheat seems to be rare on barley. The class range of 0 to 4 was maintained as in wheat but more emphasis was placed on pustule size in determining the classes (figure 1). They are described as follows:

Type 0:—Characterized by hypersensitive flecks which have no visible sporulation.

Type 1:—Uredia are small (not over 1 mm.) and surrounded by distinct necrotic areas.

Type 2:—Uredia are larger than type one (up to 2 mm.). Chlorosis is usually present but some pustules are surrounded by a necrotic area.

Type 3:—Pustules are moderately large (from 2 to 4 mm.) and occasionally coalesce. Uredia are surrounded by chlorotic or necrotic borders.

Type 4:—pustules are large (over 4 mm.) and often coalesce. Borders are usually chlorotic but sometimes necrotic.

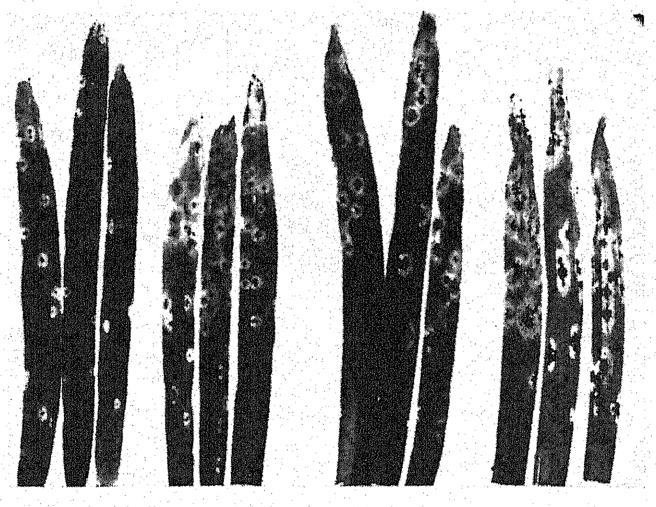
It was found desirable to affix plus and minus signs to these types to describe pustule sizes more precisely. Notes were also taken on the presence of chlorosis or necrosis.

RESULTS AND DISCUSSION

Effect of High and Low Temperature

This part of the study was based on reactions observed on 250 strains inoculated with race 15B and grown at 2 temperatures, approximately 82°F. and 70°F. The determinations under the higher temperatures were made from October to December 1951, those under the lower temperatures in March 1952.

There were marked differences in plant growth at the two temperatures. At 70°F., emergence was slower and seedlings were green with a normal type and rate of growth. At 82°F., seedlings grew more rapidly, were taller and more spindling and in general were a paler green color.



Type 1 Type 2 Type 3 Type 4

FIG. 1.—Reaction types used in classifying stem rust infection on barley seedlings.

At the high temperature, chlorosis around the rust pustules was almost universally present even in varieties which were susceptible as judged by the presence of large pustules on seedlings and by adult plant reaction. In some cases chlorosis was bordering on necrosis. Leaves deteriorated rapidly after the maximum development of pustules occurred.

At 70°F., chlorosis bordering on necrosis was most common although a few varieties had only chlorosis. Fewer pustules were present at the lower temperatures. There was usually a range in types of rust present on the same plant; in many cases the intermediate types predominated. At the lower temperatures, pustules were usually smaller than they were on the same varieties at higher temperatures. There were only minor differences at lower temperatures between seedling reaction of "susceptible" varieties and "resistant" varieties whereas at higher temperatures differences were more pronounced. Classification was found to be easier at higher temperatures as reported by Patterson.[9] It appears that complete susceptibility may have been absent in the barleys studied inasmuch as chlorosis or necrosis was almost always present.

Correlations of Reactions of Seedlings and Adult Plants

This study was made on the same group of lines as the study on effects of temperature. Notes were taken on the range of reaction types and the prevalence of rust on seedlings at two temperatures. Notes for adult plants were taken on the pustule type and prevalence of rust in percent. In order to make association tests of reactions at various stages of growth and at two temperatures, it was necessary to classify each line of barley at each stage and temperature as resistant, intermediate, or susceptible.

For seedlings this was done both on the basis of an absolute scale with class limits the same for both temperatures and on the basis of the reactions relative to standard varieties whose rust reaction was already established. The class limits used in the "absolute" scale were as follows: resistant type 2 or less; intermediate type 2+ or 3−; and susceptible type 3 or higher. The class limits

[9] *Op. cit.*

for the "relative" scale are as follows: resistant type 3— or less; intermediate type 3 or 3+; and susceptible type 4— or higher.

For adult plants, two systems of classification were employed. The first classification was made on the basis of pustule type alone and will be designated as the "pustule" scale henceforth. In this classification small pustules were called resistant while large, erumpent pustules were called susceptible. The second classification combined prevalence of rust and pustule type and will be designated as the "combined" scale. Classes for this scale were set up as follows: resistant—all plants with resistant or moderately resistant types of pustules or less than 2% of rust of any pustule type; intermediate—plants with moderately susceptible types of pustules or 2 to 10% of rust of a susceptible type; and the susceptible class included varieties with more than 10% of rust of a susceptible type.

Using these scales, each variety was classified as resistant, intermediate, or susceptible in every test in which it was grown. Double-entry tables were prepared for the comparisons listed in table 1. The χ^2 test was used to test association of the two stages compared. Table 2 lists the percentage of each reaction class under various systems of classification.

A number of conclusions may be made from table 1. The degree of association between reactions of seedlings and adults was statistically significant in all but two comparisons, each of which involved adult plants classified on the basis of pustule type alone. However, this association does not indicate perfect or near-perfect agreement as shown by table 2. There was a definite tendency for the seedlings to shift from a resistant reaction at low temperatures to a susceptible reaction at high temperatures regardless of the manner of classification at high temperatures. The frequency of adult plants in the three classes varied greatly depending upon the manner of classification. The highest agreement found was between reactions of adult plants in the greenhouse and field. Reactions of seedlings to rust were not a very good indication of reactions of adult plants except when the classes for seedlings were set up on a relative scale based on the reaction of check varieties, and when adult plants were classified on the combined scale of pustule type and prevalence. This association is of most practical interest to the breeder. In this relationship, 76% of the resistant or intermediate adults were detected as such in the seedling stage.

Table 1.—χ^2 and probability values for several comparisons of rust reactions at two stages of development and with various types of classifications.

Comparison	χ^2*	P value (independence)
Seedling (high temp. vs. low.) absolute scale	35.8470	<0.001
Seedling (high–absolute) vs. adult (combined scale)	12.9627	.01–.02
Seedling (high–relative) vs. adult (combined scale)	47.0424	< .001
Seedling (low–absolute) vs. adult (combined scale)	12.6775	.01–.02
Seedling (high–absolute) vs. adult (pustule type)	3.8382	.30–.50
Seedling (high–relative) vs. adult (pustule type)	6.2387	.10–.20
Adult (high–greenhouse) vs. adult (combined scale)	30.3186	< .001
Adult (low–greenhouse) vs. adult (combined scale)	43.0432	< .001

* Degree of freedom = 4 for a 3 × 3 table for association.

Table 2.—Frequency distribution of varieties in rust reaction classes under different systems of classification.

Stage of growth and scale	Temperature	Percentage of varieties			Total number
		R	I	S	
Seedling—relative	High	18.8	49.3	31.8	228
Seedling—absolute	High	2.6	18.9	78.5	223
Seedling—absolute	Low	41.6	45.4	13.0	238
Adult—combined	Field	67.6	16.0	16.4	238
Adult—pustule	Field	11.3	18.5	70.1	238
Adult (greenhouse)—pustule*	High	66.2	21.6	12.2	74
Adult (greenhouse)—pustule*	Low	60.8	21.5	17.7	79

* This group was taken from the same group as the rest but was selected to contain some of each reaction class. It is, therefore, not directly comparable to the other groups.

A number of explanations may be offered for the lack of complete agreement between reactions under different systems of classification. Firstly, any arbitrary classification necessarily includes human error, particularly when there is a lack of clearcut delineation between classes. Secondly, the inoculum used in the various tests was not identical. That used in the greenhouse studies was from one collection of race 15B while that used in the field consisted of a mixture of 10 collections. Perhaps races other than 15B were present in the field and not detected. Thirdly, it is possible that barley has an "adult plant" resistance similar to that reported for wheat. Evidence for this is the fact that 60% of all seedlings susceptible at high temperature were resistant as adult plants under the combined scale of pustule type and prevalence.

Sources of Resistance to Race 15B

This study was designed to test known sources of resistance to stem rust and to locate other sources if they existed. The resistance conferred by the T factor of Chevron and Peatland varieties appears to be adequate against race 15B. This is borne out by the fact that varieties resistant to most other common races of stem rust are resistant to race 15B. Of the 283 lines grown to maturity, 201 had 1% or less of rust. Allowing for the possibility of some escapes due to low prevalence of rust, there would still be strong evidence of adequate sources of resistance. Strong circumstantial evidence for this is the fact that in recent epidemics of black stem rust, most of which was determined to be race 15B, there has been very little rust on "resistant" varieties of barley such as Kindred or Peatland.

Inheritance of Reaction to Race 15B

Two crosses were studied in the F_1, F_2, and F_3 generations. The variety Minnesota 615 was used as the female in crosses with the commercial malting varieties Kindred and Montcalm. Minnesota 615 and Kindred are rust resistant in the greenhouse and field whereas Montcalm is susceptible. Minnesota 615 originated from the cross (Barbless × Peatland) × Minsturdi.

F_1 plants of the two crosses were studied as seedlings at low and high temperatures and as adults in the field and in the greenhouse at low temperatures. Unfortunately no useful data were obtained on seedlings at high temperatures due to an application of sulphur dust which greatly arrested and altered the pustules so that they were not normal in appearance or size.

At low temperature the seedlings of Minnesota 615 and Kindred were resistant with maximum pustule types of 2+ and 2–, respectively. Montcalm had type 3– to 3 reactions. F_1 hybrids were as resistant as Minnesota 615 but varied from a type 1 to 2+.

When adult plants were grown at low temperature in the greenhouse, Minn. 615 was resistant, Kindred moderately resistant, and Montcalm was susceptible. F_1 plants of both crosses were mostly resistant but a few were only moderately resistant. Adult F_1 plants grown in the field responded in the same manner during the summer of 1952.

Resistance appeared to be dominant in the F_1 of both crosses inasmuch as F_1 plants were as resistant as their most resistant parent. Some variability was evident in the reaction of Minnesota 615, Kindred, and the F_1 plants. The rust reaction of F_2 plants descended from these F_1 plants was obtained only in the field. Plants were classified as resistant and susceptible.

Table 3 summarizes the data on the F_2 generation of these two crosses. The Minn. 615 × Kindred cross was studied in 5 families involving a total of 101 plants of which only 4 were moderately susceptible and 1 susceptible. The Minn. 615 × Montcalm cross was studied in 17 families involving 464 plants, 327 of which were resistant. Three families contributed most of the deviations from a 3:1 ratio. These families had resistant to susceptible plant counts of 8:8, 9:9, and 11:10, respectively, and were among the smaller families studied.

The data obtained seem to support the hypothesis that resistance is governed by a single major factor with resistance dominant. The Minnesota 615 × Kindred cross involves two resistant parents and might be said to fail to segregate for all practical purposes.

The seedling reaction of 280 F_3 lines of Minn. 615 × Montcalm and 255 F_3 lines of Minn. 615 × Kindred were studied at high and relatively low temperatures. The adult reaction was studied in the field in 1952. These F_3 lines were a distinct group not directly descended from the F_1

Table 3.—χ^2 for homogeneity for F_2 of two barley crosses as adult plants.

Ratio Tested	d.f.	χ^2 value	Probability
Minn. 615 × Kindred			
χ^2 total of individual family fit to 3:1	4	27.9320	———
χ^2 for overall fit to 3:1 on total F_2 population	1	23.2579	<0.001
χ^2 for homogeneity	3	4.6741	.10–.20
Minn. 615 × Montcalm			
χ^2 total of individual family fit to 3:1	17	26.3188	———
χ^2 for overall fit to 3:1 for total F_2 population	1	5.0611	.05–.02
χ_2 for homogeneity	16	21.2577	.10–.20

Table 4.—Seedling rust reaction of crosses of Minn. 615 × Kindred and Montcalm at high and low temperatures with χ^2 tests for monogenic segregation.

Cross	Temperature	F_3 family number	No. of F_3 lines R	Seg	S	I	χ^2 for 1:2:1	Probability
Minn. 615 × Kindred	High	29	97	1	0	1	———*	———
		32	46	3	0	2	———	———
		35	39	17	0	0	———	———
Minn. 615 × Kindred	Low	29	75	0	24	0	———	———
		32	35	0	16	0	———	———
		35	71	0	26	0	———	———
Minn. 615 × Montcalm	High	38	32	15	2	0	44.1020	<0.001
		41	10	20	13	0	0.6279	.70–.80
		44	38	62	35	0	1.0926	.70–.80
Minn. 615 × Montcalm	Low	38	44	35	7	0	35.2353	< .001
		41	4	34	2	0	19.8010	< .001
		44	35	71	22	0	4.1718	.10–.20

* χ^2 was not calculated because of a lack of clear-cut segregation.

Table 5.—Adult reactions of F_3 lines to ten collections of race 15B and χ^2 for fit to 1:2:1 ratio.

Cross	F_3 family number	No. of F_3 lines Res.	Seg.	Sus.	χ^2 for 1:2:1	Probability
Minn. 615 × Kindred	29	88	1	4	———	———
Minn. 615 × Kindred	32	41	0	1	———	———
Minn. 615 × Kindred	35	81	0	0	———	———
Minn. 615 × Montcalm	38	13	34	17	0.7500	0.50–0.70
Minn. 615 × Montcalm	41	10	20	13	.6279	.70– .80
Minn. 615 × Montcalm	44	35	65	20	4.5833	.10– .20

and F_2 lines already discussed. Each family of F_3 lines traced back to an F_2 population that was derived from several F_1 plants having the same parent plants. No selection for rust reaction had been made in the F_2 generation.

Table 4 gives rust reactions of seedlings of six F_3 families at high and low temperatures. Seedlings notes were taken on the range of reaction types present and the number of plants of each reaction type recorded. The reaction of checks and parents was used as the basis for classifying seedlings as resistant, intermediate, or susceptible. The cross Minn. 615 × Kindred failed to segregate in a clear-cut manner. At low temperature difficulty was experienced in classifying lines due to the small differences found. At high temperature none of the lines was uniformly susceptible though some had plants which appeared more susceptible than either Minn. 615 or Kindred. The Minn. 615 × Montcalm cross gave a good fit to a 1:2:1 ratio at high temperature except for 1 family, number 38 which was tested in June when greenhouse temperatures were often uncontrollably high.

The adult plant reactions of the F_3 lines were determined in the field using a composite of 10 collections of race 15B for inoculum. These lines were classified as resistant, segregating, or susceptible with results shown in table 5. Each of the 3 families from the cross Minn. × Montcalm gave a good fit to a ratio of 1 resistant: 2 segregating: 1 susceptible. Five lines from the Minnesota 615 × Kindred cross had susceptible types of pustules but the prevalence of rust on these lines was less than 1%. Susceptible varieties in the same nursery had about 30% rust so that for practical purposes these lines may be considered resistant also. It should be emphasized that the adult plant reaction under field conditions is of greatest importance agronomically.

On the whole the evidence for monogenic segregation for reaction to 15B appears to be fairly good. This conclusion is based primarily upon seedling reactions at high temperature, and adult reactions in the field. Discrepencies under low temperatures and in certain other instances are not easily explained. The expression of modifying genes under certain environmental conditions such as the greenhouse at low temperature is a distinct possibility. There also was some evidence that there may have been some heterogeneity or heterozygosity among the original parental plants. There is, moreover, the possibility that the inoculum used in the greenhouse may have contained slight mixtures of races other than 15B or of biotypes within 15B.

SUMMARY

1. Seedling reactions of about 250 barley varieties to race 15B of stem rust were determined at 70°F. and 82°F. A scale was devised for seedling reactions based on relative size of pustule. Chlorosis was present at both temperatures, but necrosis was more abundant at the lower temperature. On almost all plants, there was a considerable range in pustule types present. The higher temperature was found to be better for classifying seedlings.

2. Correlation studies were made by means of χ^2 for association among reactions to race 15B of stem rust of barley varieties at two stages of maturity and two temperatures using various methods of classification. A statistically significant association was found for six out of eight comparisons. Of greatest practical interest is the close relationship of seedling reaction at high temperature on the "relative" scale with the field reaction on the "combined" scale.

3. There were adequate sources of resistance to the collections of race 15B of stem rust used in this study. The Peatland or Chevron factor, T, appeared to govern resistance.

4. The inheritance of mode of reaction to race 15B was studied in the F_1, F_2, and F_3 generations of the crosses Minn. 615 × Kindred and Minn. 615 × Montcalm. Reaction to rust apparently was conditioned by one major factor with resistance dominant. Some indication of minor or modifying factors was present.

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Chemical Defoliation of Cotton
IV. Lodging in Bottom Defoliated Cotton[1]

Lamar C. Brown and Angus H. Hyer[2]

ACALA-44, a commercial variety of Upland cotton cultivated extensively in Arizona, has a tendency to lodge toward the end of the growing season. Since lodging aggravates boll rotting and interferes with efficient mechanical harvesting, any cultural practice that lessens the difficulty would be advantageous.

It has been observed that lodging was not as pronounced in chemically bottom defoliated cotton as in non-defoliated cotton. An experiment was designed, therefore, to determine *(a)* whether or not lodging actually is reduced when cotton is bottom defoliated, *(b)* if the difference is due to the chemical defoliant or to leaf removal *per se,* and *(c)* if variety interactions occur.

Several varieties which had exhibited differences with respect to lodging in other experiments[3] were chosen for an experiment conducted in the field at Sacaton, Ariz., in 1954. The varieties tested were two Upland cottons, Acala-44 and AxD, and two American–Egyptian cottons, Pima S-1 and 1-71. Since the degree of lodging usually is more pronounced in closely spaced cotton, plants were spaced at approximately 3 inches in the row. The lower portion of the plants, one-third of the plant height from the ground level, was defoliated when the lower bolls had reached maturity. Bottom defoliation was accomplished on Sept. 14 by two entirely different methods: *(1)* a chemical defoliant, AERO Cyanamid Soluble (monosodium cyanamide, 85%), applied with ground machinery at a rate of 8 pounds per acre, and *(2)* stripping the lower leaves by hand. Non-defoliated plants constituted the control plots. Treatments were replicated three times in a split-plot design with varieties as main plots and treatments as sub-plots.

The amount of lodging was determined on Nov. 1. This date was considered as an appropriate time to harvest the crop. The perpendicular distance from the ground to the tip of the inclined main stalk, and also the length of the main stalk, were determined for plants in each sub-plot. The cosine of the angle that the plant made with the perpendicular was determined from these measurements and then converted into degrees. Consequently, a high value in table 1 would indicate a greater amount of lodging than a low value.

The degree of lodging was significantly less in bottom defoliated cotton regardless of the method of leaf removal. The mean differences between the control and treatments *(1)* and *(2)*, respectively, were 18 and 15 degrees. The mean difference of 3 degrees between the chemically defoliated and the "hand" defoliated plants was not significant. It would appear, therefore, that leaf removal *per se,* regardless of the method, is the determining factor in the reduction of lodging in bottom defoliated cotton.

Since the analysis of variance gave no significant treatment × variety interactions, it is concluded that the varieties responded in the same manner to the treatments.

Bottom defoliation of rank cotton hastens the opening of mature bolls, reduces the possibility of boll rot, and also acts as a late season method of weed control, i.e., a substitute for a late cultivation. The reduced amount of lodging found in bottom defoliated cotton, which would facilitate mechanical harvesting, points up an advantage of bottom defoliation additional to those enumerated previously.[4]

The data from this experiment indicate a need for further investigations to ascertain the reasons for a reduction in lodging occasioned by removal of the lower leaves.

[4] Brown, L. C. Chemical Defoliation of Cotton. I. Bottom leaf defoliation. Agron. Jour. 45:314–316. 1953.

Table 1.—Angle of bend expressed in degrees as measured from the perpendicular.

Treatments	Variety				Mean
	A-44	AxD	P S-1	1–71	
1. Chemically defoliated	37°	26°	40°	32°	34°
2. Hand defoliated	39°	29°	42°	38°	37°
3. Control	55°	42°	53°	57°	52°
Mean	44°	32°	45°	42°	41°

L.S.D. for comparing variety means: 5% = 7°
L.S.D. for comparing treatment means: 5% = 4°; 1% = 5°
No significant interaction between varieties and treatments

[1] Supported in part by a grant from the American Cyanamid Co. Received April 4, 1955.

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[3] Brown, L. C., and Rhyne, C. L. Unpublished data.

Inheritance of Reaction to *Ascochyta caulicola* in Sweetclover (*Melilotus alba*)[1]

H. J. Gorz[2]

STEM canker or gooseneck disease of sweetclover caused by the fungus *Ascochyta caulicola* Laub. has become prevalent in the North Central States since 1946 and is considered to be one of the major diseases of sweetclover in this region. The disease occurs in most areas where sweetclover grows. The high incidence of susceptibility to stem canker in breeding lines and the lack of progress from random selection of resistant plants suggested the present genetic study to permit selection for true-breeding resistance to *A. caulicola*.

The disease is characterized by silvery-white lesions of variable size with a brown halo, located on the stem, petioles, and leaf midribs of susceptible plants. Lesions are smaller and more isolated on the upper part of the plant but often girdle the lower stems through coalescence of the individual cankers. Numerous black pycnidia give the lesions a stippled appearance except when the lesions are old and the pycnidia have been eroded and emptied by rain. Heavily infected stems are swollen, retarded in their development, and severely twisted at the apical end, while the leaves are reduced in number and size.

Histological studies of diseased stems and a complete description of the morphological characteristics of the fungus were reported by Laubert[3] who also noted the first occurrence of stem canker in Germany in 1903 and named the causal organism. Stem canker has been observed in several countries other than the United States but no reference to previous work on the inheritance of disease reaction was found in the literature.

[3] Laubert, R. *Ascochyta caulicola*, ein neuer Krankheitserreger des Steinklees. Arb. Biol. Reichsanstalt f. Land-u. Forstwirtschaft 3:441–443. 1903.

MATERIALS AND METHODS

Parent plants used in the inheritance study were selected from a replicated field nursery seeded in 1947 in which each line was derived from open-pollinated seed from a single plant. A severe infestation occurred with readings up to 94% of susceptible plants in certain lines. The percentage of susceptible plants in each line was determined by reading the disease reaction of 100 plants in each of 2 replicates. One-year-old plants were selected during the winter of 1947–48 from the two most resistant and four most susceptible lines in the nursery and were transplanted to pots in the greenhouse to be used as resistant and susceptible parents, respectively, in the genetic study. Plants secured from any one line in the field were assigned a code letter with subscript numbers indicating individual plants within the line.

[1] Cooperative investigations of the Field Crops Research Branch, A.R.S., U.S.D.A., and the Departments of Genetics (Paper No. 581) and Agronomy, University of Wisconsin. Received April 6, 1955.

[2] Formerly graduate assistant in Genetics and Agronomy, University of Wisconsin, now Cooperative Agent (Geneticist), Field Crops Research Branch, A.R.S., U.S.D.A. and the University of Nebraska, Lincoln, Nebr. The writer wishes to express his appreciation to Dr. W. K. Smith for valuable help and guidance throughout the investigation and in preparation of the manuscript. Gratitude is also expressed to Dr. F. R. Jones and Dr. J. G. Dickson for assistance in the pathological phases of this study, and to Dr. J. H. Torrie for suggestions on some statistical aspects.

Emasculation of the florets before crossing was done by a modification of the method described by Kirk.[4] Reciprocal crosses were made between the original parent plants, which did not carry marker genes by which the seeds resulting from self-pollination could be eliminated. Marker genes were present in non-reciprocal crosses producing 490 of 829 F_1 seeds obtained from 109 crosses between plants whose genotypes had been revealed by the ratios of their selfed progenies.

A series of preliminary studies on the optimum stage of growth for inoculation, effect of temperature and moisture at the time of inoculation, region of fungal penetration, and cultural characteristics of the causal organism was conducted to facilitate the genetic investigation. Selfed seed from plants homozygous for disease reaction was used in these studies.

Seed used in the genetic study was derived from individual self-pollinated plants in each of the generations from parent to F_3. Each lot of seed was divided into several smaller lots and planted in separate flats at different times. Scarification was effected by scratching the seed coat near the tip of the cotyledon with a razor blade. S_1 seeds of the parents and seeds of a uniformly resistant and a uniformly susceptible line were planted in each flat as a measure of the uniformity of infection. The seedlings were grown in the greenhouse and inoculated when three to five trifoliolate leaves were expanded. A suspension of spores was prepared by soaking diseased sweetclover stems in tap water and straining through a single layer of cheesecloth. The diseased stems were collected each summer from susceptible plants in the field and were dried and stored indoors at room temperature until needed. The spore suspension was atomized on the seedlings and the flats held in a moist chamber with a saturated atmosphere for 36 hours at 68 to 72°F. Optimum chamber temperatures were difficult to maintain during the summer months. However, opening the doors of the chamber slightly to increase evaporation and allowing cold water (about 57°F.) to flow into the atomizer kept the temperature below 80°F. during the hottest part of the day. The plants were held in the greenhouse for 2 to 3 weeks after inoculation before disease readings were recorded.

The critical factor in distinguishing susceptible and resistant plants was the presence or absence of sporulation of the fungus. The disease reaction of individual plants was recorded and the identity of all plants was maintained throughout the study. Resistant plants were separated into five classes ranging from no reaction or small flecks to large blackened areas. Pycnidia were not formed although the fungus apparently had penetrated and destroyed some stem tissue. Six categories were used to differentiate susceptible plants based on the area of stem affected and the size and number of lesions containing visible pycnidia. The first susceptible class was phenotypically intermediate between resistance and susceptibility because the small, indistinct lesions were interspersed with resistant flecks, but tests of progeny from these plants indicated that they were susceptible. Accurate reading of disease reaction in plants with the intermediate phenotype was difficult and some misclassification probably occurred. The five resistant classes were combined in summarization of the data, as were the six susceptible classes. Consolidation of the readings did not alter the genetic analysis.

Results of crosses involving parents of similar genotype or crosses that produced identical F_1 genotypes were combined in summarizing the data. Similar ratios within the same generation also were combined. Heterogeneity χ^2 values were calculated to determine whether the individual components to be combined were homogeneous. The correction for continuity was applied in calculating the χ^2's for the pooled data, but uncorrected values were used in calculating the heterogeneity χ^2's.

[4] Kirk, L. E. Abnormal seed development in sweet clover species crosses—a new technique for emasculating sweet clover flowers. Sci. Agric. 10:321–327. 1930.

EXPERIMENTAL RESULTS

Ratios of plants of specific disease reaction, probability values and genotypes of P_1, F_1, F_2 and F_3 lines from seven crosses involving six parental genotypes are presented in tables 1 to 4. The results of individual crosses are shown in tables 3 and 4, while tables 1 and 2 have pooled data from three and two similar crosses, respectively.

Analysis of the data suggests the presence of two interacting gene pairs, symbolized as *E/e* and *G/g*. The symbol "*G*" refers to the common name of "gooseneck" often applied to this disease. The dominant gene *E* is epistatic to *G* and plants with the *E* allele are resistant. The dominant gene *G* renders a plant susceptible if the recessive alleles *ee* are present. A plant homozygous for both recessive gene pairs also is resistant since the dominant *G* is necessary for susceptibility. Selfed progenies can be all resistant, all susceptible, or in the ratio of 3:1, 13:3 or 1:3 of resistant to susceptible in each case.

The data in tables 1, 2, and 3 are in satisfactory agreement with expectation although some discrepancies are noted in each of the tables. Susceptible plants that have escaped infection are found in progeny of A_2 and in F_2-4 and F_3-3 in table 1. Similar escapes are noted in tables 2 and 3. When progenies from six such apparently resistant F_1 and F_2 plants in tables 1 and 2 were inoculated, three were all susceptible while the remaining three were in the ratio of one resistant to three susceptible, indicating a susceptible genotype in each of the six plants. Three probability values between 0.05 and 0.01 were found: two appear in ratios of 1:3, and one in a 13:3 ratio. The significant differences in tables 2 and 3 were apparent only after the data from similar ratios were combined. The nonsignificant heterogeneity χ^2 values indicate consistency in each group of pooled progenies. It is, however, recognized that assignment of progenies to either a 3:1 or 13:3 ratio tends to result in a greater homogeneity among individual lines grouped under a given ratio. It would also tend to give an excess of susceptibles in the 3:1 group and an excess of resistant in the 13:3.

The 13:3 ratios shown in tables 1, 3, and 4 were derived from homogeneous selfed progenies of 2 P_1, 10 F_1 and 3 F_2 plants. Thirteen of the 15 progenies had an excess of resistant plants. A total of 790:138 was obtained with bulking which is a ratio of 17.3:3 instead of the expected 13:3. Linkage between the *E* and *G* genes was studied as a possible cause of the deviation from expected. The surplus of resistant plants could be explained by linkage in

Table 1.—Distribution of disease reaction in progenies from three crosses* of resistant × susceptible parents giving identical F_1 genotypes.

Generation	Code	Number of families	Disease reaction ratios		Probability values		Genotype
			Observed	Theoretical	Pooled data χ^2	Heterogeneity χ^2	
P_1	A_1	1	50:22	3:1	0.30–0.50	—	*EeGG*
P_1	A_2	1	2:62	All S	—	—	*eeGG*
P_1	B	1	9:60	1:3	.02– .05	—	*eeGg*
P_1	D_1, D_2	2	141:21	13:3	.05– .10	0.05–0.10	*EeGg*
F_1*		6	36:28	1:1	.30– .50	.30– .50	
F_2	1	11	629:231	3:1	.20– .30	.90– .95	*EeGG*
F_2	2	6	286:56	13:3	.20– .30	.95– .98	*EeGg*
F_2	3	3	39:111	1:3	.80– .90	.30– .50	*eeGg*
F_2	4	8	7:257	All S	—	—	*eeGG*
F_3	1 from F_2–1	3	144:0	All R	—	—	*EEGG*
F_3	2 from F_2–1	14	639:228	3:1	.30– .50	.70– .80	*EeGG*
F_3	3 from F_2–1	5	6:285	All S	—	—	*eeGG*
F_3	4 from F_2–3	1	15:43	1:3	.99	—	*eeGg*
F_3	5 from F_2–4	3	0:33	All S	—	—	*eeGG*

* Includes reciprocal crosses between $A_1 \times B$, $A_2 \times D_1$, and $A_2 \times D_2$.
† Number of resistant (R) plants: susceptible (S) plants in all crosses.

Table 2.—Distribution of disease reaction in progenies from two crosses* of heterozygous susceptible × homozygous susceptible parents.

Generation	Code	Number of families	Disease reaction ratios		Probability values		Genotype
			Observed	Theoretical	Pooled data χ^2	Heterogeneity χ^2	
P_1	A_3, H	2	1:150	All S	—	—	*eeGG*
P_1	D_3, E	2	40:117	1:3	0.90–0.95	0.30–0.50	*eeGg*
F_1*		4	1:35	All S	—	—	
F_2	5	10	149:550	1:3	.02– .05	.10– .20	*eeGg*
F_2	6	12	15:412	All S	—	—	*eeGG*
F_3	6 from F_2–5	3	102:53	All R	—	—	*eegg*
F_3	7 from F_2–5	7	52:201	1:3	.10– .20	.50– .70	*eeGg*
F_3	8 from F_2–5	11	7:370	All S	—	—	*eeGG*
F_3	9 from F_2–6	4	0:58	All S	—	—	*eeGG*

* Includes reciprocal crosses between $A_3 \times E$ and $D_3 \times H$.

Table 5.—Frequency of genotypes occurring in F_1 and F_2 populations as revealed by F_2 and F_3 ratios, respectively.

Generation	Source of data	Genotypes crossed in P_1 or selfed in F_2	No. of each genotype observed in progeny: *EEGG*	*EeGG*	*EeGg*	*eeGG*	*eeGg*	*eegg*	Expected ratio	P value
F_2	Table 1	*EeGG* × *eeGg*	—	11	6	8	3	—	1:1:1:1	0.10–0.20
F_2	3	*EEGg* × *eeGG*	—	4	4	—	—	—	1:1	.99
F_2	2	*eeGG* × *eeGg*	—	—	—	13	10	—	1:1	.50– .70
F_3	1	*EeGG*	3	14	—	5	—	—	1:2:1	.30– .50
F_3	1, 2	*eeGg*	—	—	—	11	8	3	1:2:1	.02– .05
F_3	1, 2	*eeGG*	—	—	—	7	—	—	All S	——

Table 6.—Distribution of disease reaction in crosses between plants of known genotypes.

Genotypes crossed	Number of crosses	Disease reaction ratios: Observed	Disease reaction ratios: Theoretical	Probability values: Pooled data χ^2	Probability values: Heterogeneity χ^2
EEGG × *EEGG*	4	27:0	All R	——	——
EEGG × *eeGG*	41	286:0	All R	——	——
EE × *EeGG*	1	8:0	All R	——	——
EE × *EeGg*	2	17:0	All R	——	——
eeGg × *EEGG*	1	5:1	All R	——	——
eegg × *EEGG*	2	10:0	All R	——	——
EeGG × *EeGg*	1	4:2	3:1	.99	——
EeGG × *eeGG*	15	60:72	1:1	.30–0.50	0.20–0.30
EeGg × *eeGG*	2	6:5	1:1	.99	.50– .70
EeGg × *eeGg*	2	6:4	5:3	.80– .90	.10– .20
eeGG × *Eegg*	3	15:23	1:1	.20– .30	.05– .10
eeGg × *eeGg*	5	10:25	1:3	.70– .80	.10– .20
eeGG × *eeG*	30	5:238	All S	——	——

selfed progeny that were uniformly susceptible, indicating escapes or misclassification. The discrepancies in table 4 may result from the action of an additional gene or modifying genes in this cross, or variability in the fungus.

The frequencies of genotypes occurring in F_1 and F_2 populations as indicated by F_2 and F_3 progenies are presented in table 5. Data from table 4 are not included. Since the information in this table was compiled from the data in tables 1 to 3 after the genetic hypothesis had been formulated, it constitutes a critical test of the hypothesis. The observed frequencies of genotypes were in satisfactory agreement with expected except for one significant χ^2 value calculated from the frequency of progenies of plants of genotype *eeGg*. The characteristics of progeny from plants of this genotype have already been given.

As a further test of the validity of the genetic hypothesis, 109 crosses were made between plants whose genotype for disease reaction had been determined during the course of the investigation. Data from the crosses, which involved 13 different genotypic combinations, are found in table 6. No significant deviations from expected results were encountered. Recessive marker genes for low coumarin content were present in the female parents of 490 of the 829 F_1 seeds obtained. A coumarin test of the F_1 seedlings revealed that 5.51% of the 490 seeds was the result of self-pollination. This is an indication of the percentage of selfing which probably occurred in crosses that did not have marker genes.

DISCUSSION

The discovery that resistance to stem canker in sweetclover is conditioned by two interacting gene pairs has revealed the source of difficulty experienced by sweetclover breeders in developing a true-breeding resistant line by selecting resistant plants. A breeding nursery composed only of resistant plants might consist of a mixture of the seven possible resistant genotypes. Only three of the seven resistant genotypes would give no susceptible offspring when cross-pollinated with each of the other genotypes. Random cross-pollination by bees among resistant plants in a breeding nursery would result in a highly heterozygous population that would continue to produce a proportion of susceptible plants even though all susceptible plants in the previous generation had been eliminated before flowering. Knowledge of the presence and action of genes conditioning resistance provides the necessary information for development of sweetclover varieties that will be homozygous for resistance.

The most convincing evidence supporting the proposed genetic hypothesis was found in crosses involving the segregation of the epistatic gene pair, *Ee*, in the presence of the dominant gene for susceptibility, *G*. Crosses of this type gave distinct reactions of susceptibility and resistance that were widely separated and easily classified, resulting in ratios that closely approximated those expected. The ratios of F_1 progenies from crosses between plants of known genotypes (table 6), and the genotypic ratios observed in F_1 and F_2 populations (table 5), were in satisfactory agreement with expected ratios, thereby substantiating the conclusions drawn from the genetic data in tables 1 to 4.

Observed results in crosses involving the segregation of the susceptible gene pair in the absence of the dominant epistatic gene do not fit the expected as closely as in the

above crosses, but no highly significant deviations were obtained. The disease reaction was less clearly defined, resulting in many plants with an intermediate reaction that were difficult to classify, and ratios were influenced by the weaker resistance displayed by the homozygous recessive genotype under optimum conditions for infection. Jones, Briggs, and Blanchard[6] reported similar results with the homozygous recessive genotype in a study of the inheritance of resistance to the pea aphid in alfalfa hybrids.

The present genetic study has provided information for the development of a more precise method of eliminating susceptibility from sweetclover lines. The genotype providing double insurance for resistance would be *EEgg*, but the detection of this genotype would not be feasible because the *gg* portion cannot be determined with a practical, one-generation method. Hence, *EE*— would be a less desirable but more practical genotype to a plant breeder and would give adequate resistance to stem canker under field conditions. Determination of the *EE*— genotype in individual plants would require tester plants with a distinct marker phenotype controlled by a single, recessive pair of genes. The tester plants also should be susceptible to stem canker with the genotype *eeGG*. Plants to be tested would be crossed on the tester plants and selfs eliminated by means of the marker gene. Male parents giving rise to one or more susceptible F_1 plants would be discarded. All surviving plants would be of genotype *EE*—. Seven or more F_1 plants from each cross should be inoculated as this would result in probabilities of less than 0.01 that a male parent with a recessive *e* gene would not produce a susceptible offspring. Inoculation of self-pollinated lines would eliminate two of the four resistant genotypes containing *e*, but *Eegg* and *eegg* would not be removed because all selfed progeny would be resistant and therefore indistinguishable from the selfed progeny of the *EE*— resistant genotypes.

[6] Jones, L. G., Briggs, Fred N., and Blanchard, R. A. Inheritance of resistance to the pea aphid in alfalfa hybrids. Hilgardia 20:9–17. 1950.

SUMMARY

The inheritance of reaction to stem canker or gooseneck disease of sweetclover caused by *Ascochyta caulicola* Laub. was investigated. Two pairs of interacting genes, *E/e* and *G/g*, were found to affect the reaction of sweetclover plants to this disease. The dominant gene for susceptibility, *G*, was effective only when the epistatic gene *E* was not present. Plants with the homozygous recessive genotype *eegg* were resistant as the dominant gene *G* is necessary for susceptibility, but the resistance was apparently less effective under optimum conditions than that controlled by the epistatic gene *E*.

Susceptibility may be eliminated in breeding lines by crossing plants of unknown genotype to homozygous susceptible tester plants containing a recessive marker for the elimination of selfs. The absence of susceptibility in 7 to 10 F_1 plants would reveal the presence of the resistant *EE*— genotype, which would maintain resistance in the progenies of plants in a cross- or self-pollinated nursery.

How Well is Corn Seed-Treated in Commercial Practice?[1]

Paul E. Hoppe and A. H. Wright[2]

THERE is little in the literature concerning the question raised in the title of this article. Studies on the effectiveness of corn seed treatments have been neglected mainly because of the lack of suitable laboratory methods for making the necessary tests.

The development of the rolled towel technique for corn cold tests at the Wisconsin Agricultural Experiment Station in 1950 provided a simple laboratory method for testing the adequacy of treatment with fungicides. This method was used in a cooperative study with the Wisconsin Seed Certification Service in a 2-year survey to determine how effectively seed producers were treating their seed. In Wisconsin, treatment of hybrid seed corn with a fungicide is a requirement for certification. A statement from the producer that his seed was treated usually has been accepted by the Seed Certification Service.

To check the accuracy of the rolled towel technique, all samples were also tested by the older cold test method in the walk-in refrigerator. The details of procedure and the results obtained in the survey are reported here.

[1] Received April 6, 1955.

[2] Associate Pathologist, Field Crops Research Branch, A.R.S., U.S.D.A., and the Wisconsin Agr. Exp. Station; and Professor of Agronomy in charge of Wisconsin Seed Corn Certification Service, respectively.

METHODS

Seed samples collected by the Wisconsin Seed Certification Service for certification in 1952 and 1953 were tested. The 1952 study included 79 samples of new seed from the previous 1951 crop, from 18 seed producers. In 1953, 441 samples were tested from 84 producers. Included among these were some carry-over lots from the 1951, 1950 and 1949 crops.

Standard germination tests on all samples were made in the seed certification laboratory. Seed from each sample then was retreated with *Arasan* (50% thiram) applied by the excess method, the excess fungicide being removed from the kernels by screening, and leaving them coated with the maximum amount that would adhere without a "sticker". The retreated kernels then were tested for germination in the cold tests against the seed as treated originally by the producers. Increase in the germination of the retreated seed over that of the original treatment was considered as an indication of ineffective treatment on the part of the producer.

Cold Test Techniques

In the rolled towel method, 50 kernels first were placed on muck soil spread about ⅛-inch deep on double, wet paper towels. A third wet towel was laid over the kernels and the whole rolled loosely into a "doll". The "dolls" were placed in a special alumi-

Table 5.—Frequency of genotypes occurring in F_1 and F_2 populations as revealed by F_2 and F_3 ratios, respectively.

Generation	Source of data	Genotypes crossed in P_1 or selfed in F_2	No. of each genotype observed in progeny						Expected ratio	P value
			EEGG	*EeGG*	*EeGg*	*eeGG*	*eeGg*	*eegg*		
	Table									
F_2	1	*EeGG* × *eeGg*	—	11	6	8	3	—	1:1:1:1	0.10–0.20
F_2	3	*EEGg* × *eeGG*	—	4	4	—	—	—	1:1	.99
F_2	2	*eeGG* × *eeGg*	—	—	—	13	10	—	1:1	.50– .70
F_3	1	*EeGG*	3	14	—	5	—	—	1:2:1	.30– .50
F_3	1, 2	*eeGg*	—	—	—	11	8	3	1:2:1	.02– .05
F_3	1, 2	*eeGG*	—	—	—	7	—	—	All S	———

Table 6.—Distribution of disease reaction in crosses between plants of known genotypes.

Genotypes crossed	Number of crosses	Disease reaction ratios		Probability values	
		Observed	Theoretical	Pooled data χ^2	Heterogeneity χ^2
EEGG × *EEGG*	4	27:0	All R	———	———
EEGG × *eeGG*	41	286:0	All R	———	———
EE × *EeGG*	1	8:0	All R	———	———
EE × *EeGg*	2	17:0	All R	———	———
eeGg × *EEGG*	1	5:1	All R	———	———
eegg × *EEGG*	2	10:0	All R	———	———
EeGG × *EeGg*	1	4:2	3:1	.99	———
EeGG × *eeGG*	15	60:72	1:1	.30–0.50	0.20–0.30
EeGg × *eeGG*	2	6:5	1:1	.99	.50– .70
EeGg × *eeGg*	2	6:4	5:3	.80– .90	.10– .20
eeGG × *Eegg*	3	15:23	1:1	.20– .30	.05– .10
eeGg × *eeGg*	5	10:25	1:3	.70– .80	.10– .20
eeGG × *eeG*	30	5:238	All S	———	———

selfed progeny that were uniformly susceptible, indicating escapes or misclassification. The discrepancies in table 4 may result from the action of an additional gene or modifying genes in this cross, or variability in the fungus.

The frequencies of genotypes occurring in F_1 and F_2 populations as indicated by F_2 and F_3 progenies are presented in table 5. Data from table 4 are not included. Since the information in this table was compiled from the data in tables 1 to 3 after the genetic hypothesis had been formulated, it constitutes a critical test of the hypothesis. The observed frequencies of genotypes were in satisfactory agreement with expected except for one significant χ^2 value calculated from the frequency of progenies of plants of genotype *eeGg*. The characteristics of progeny from plants of this genotype have already been given.

As a further test of the validity of the genetic hypothesis, 109 crosses were made between plants whose genotype for disease reaction had been determined during the course of the investigation. Data from the crosses, which involved 13 different genotypic combinations, are found in table 6. No significant deviations from expected results were encountered. Recessive marker genes for low coumarin content were present in the female parents of 490 of the 829 F_1 seeds obtained. A coumarin test of the F_1 seedlings revealed that 5.51% of the 490 seeds was the result of self-pollination. This is an indication of the percentage of selfing which probably occurred in crosses that did not have marker genes.

DISCUSSION

The discovery that resistance to stem canker in sweetclover is conditioned by two interacting gene pairs has revealed the source of difficulty experienced by sweetclover breeders in developing a true-breeding resistant line by selecting resistant plants. A breeding nursery composed only of resistant plants might consist of a mixture of the seven possible resistant genotypes. Only three of the seven resistant genotypes would give no susceptible offspring when cross-pollinated with each of the other genotypes. Random cross-pollination by bees among resistant plants in a breeding nursery would result in a highly heterozygous population that would continue to produce a proportion of susceptible plants even though all susceptible plants in the previous generation had been eliminated before flowering. Knowledge of the presence and action of genes conditioning resistance provides the necessary information for development of sweetclover varieties that will be homozygous for resistance.

The most convincing evidence supporting the proposed genetic hypothesis was found in crosses involving the segregation of the epistatic gene pair, *Ee*, in the presence of the dominant gene for susceptibility, *G*. Crosses of this type gave distinct reactions of susceptibility and resistance that were widely separated and easily classified, resulting in ratios that closely approximated those expected. The ratios of F_1 progenies from crosses between plants of known genotypes (table 6), and the genotypic ratios observed in F_1 and F_2 populations (table 5), were in satisfactory agreement with expected ratios, thereby substantiating the conclusions drawn from the genetic data in tables 1 to 4.

Observed results in crosses involving the segregation of the susceptible gene pair in the absence of the dominant epistatic gene do not fit the expected as closely as in the

above crosses, but no highly significant deviations were obtained. The disease reaction was less clearly defined, resulting in many plants with an intermediate reaction that were difficult to classify, and ratios were influenced by the weaker resistance displayed by the homozygous recessive genotype under optimum conditions for infection. Jones, Briggs, and Blanchard[6] reported similar results with the homozygous recessive genotype in a study of the inheritance of resistance to the pea aphid in alfalfa hybrids.

The present genetic study has provided information for the development of a more precise method of eliminating susceptibility from sweetclover lines. The genotype providing double insurance for resistance would be *EEgg*, but the detection of this genotype would not be feasible because the *gg* portion cannot be determined with a practical, one-generation method. Hence, *EE*— would be a less desirable but more practical genotype to a plant breeder and would give adequate resistance to stem canker under field conditions. Determination of the *EE*— genotype in individual plants would require tester plants with a distinct marker phenotype controlled by a single, recessive pair of genes. The tester plants also should be susceptible to stem canker with the genotype *eeGG*. Plants to be tested would be crossed on the tester plants and selfs eliminated by means of the marker gene. Male parents giving rise to one or more susceptible F_1 plants would be discarded. All surviving plants would be of genotype *EE*—. Seven or more F_1 plants from each cross should be inoculated as this would result in probabilities of less than 0.01 that a male parent with a recessive *e* gene would not produce a susceptible offspring. Inoculation of self-pollinated lines would eliminate two of the four resistant genotypes containing *e*, but *Eegg* and *eegg* would not be removed because all selfed progeny would be resistant and therefore indistinguishable from the selfed progeny of the *EE*— resistant genotypes.

[6] Jones, L. G., Briggs, Fred N., and Blanchard, R. A. Inheritance of resistance to the pea aphid in alfalfa hybrids. Hilgardia 20:9–17. 1950.

SUMMARY

The inheritance of reaction to stem canker or gooseneck disease of sweetclover caused by *Ascochyta caulicola* Laub. was investigated. Two pairs of interacting genes, *E/e* and *G/g*, were found to affect the reaction of sweetclover plants to this disease. The dominant gene for susceptibility, *G*, was effective only when the epistatic gene *E* was not present. Plants with the homozygous recessive genotype *eegg* were resistant as the dominant gene *G* is necessary for susceptibility, but the resistance was apparently less effective under optimum conditions than that controlled by the epistatic gene *E*.

Susceptibility may be eliminated in breeding lines by crossing plants of unknown genotype to homozygous susceptible tester plants containing a recessive marker for the elimination of selfs. The absence of susceptibility in 7 to 10 F_1 plants would reveal the presence of the resistant *EE*— genotype, which would maintain resistance in the progenies of plants in a cross- or self-pollinated nursery.

How Well is Corn Seed-Treated in Commercial Practice?[1]

Paul E. Hoppe and A. H. Wright[2]

THERE is little in the literature concerning the question raised in the title of this article. Studies on the effectiveness of corn seed treatments have been neglected mainly because of the lack of suitable laboratory methods for making the necessary tests.

The development of the rolled towel technique for corn cold tests at the Wisconsin Agricultural Experiment Station in 1950 provided a simple laboratory method for testing the adequacy of treatment with fungicides. This method was used in a cooperative study with the Wisconsin Seed Certification Service in a 2-year survey to determine how effectively seed producers were treating their seed. In Wisconsin, treatment of hybrid seed corn with a fungicide is a requirement for certification. A statement from the producer that his seed was treated usually has been accepted by the Seed Certification Service.

To check the accuracy of the rolled towel technique, all samples were also tested by the older cold test method in the walk-in refrigerator. The details of procedure and the results obtained in the survey are reported here.

[1] Received April 6, 1955.

[2] Associate Pathologist, Field Crops Research Branch, A.R.S., U.S.D.A., and the Wisconsin Agr. Exp. Station; and Professor of Agronomy in charge of Wisconsin Seed Corn Certification Service, respectively.

METHODS

Seed samples collected by the Wisconsin Seed Certification Service for certification in 1952 and 1953 were tested. The 1952 study included 79 samples of new seed from the previous 1951 crop, from 18 seed producers. In 1953, 441 samples were tested from 84 producers. Included among these were some carry-over lots from the 1951, 1950 and 1949 crops.

Standard germination tests on all samples were made in the seed certification laboratory. Seed from each sample then was retreated with *Arasan* (50% thiram) applied by the excess method, the excess fungicide being removed from the kernels by screening, and leaving them coated with the maximum amount that would adhere without a "sticker". The retreated kernels then were tested for germination in the cold tests against the seed as treated originally by the producers. Increase in the germination of the retreated seed over that of the original treatment was considered as an indication of ineffective treatment on the part of the producer.

Cold Test Techniques

In the rolled towel method, 50 kernels first were placed on muck soil spread about ⅛-inch deep on double, wet paper towels. A third wet towel was laid over the kernels and the whole rolled loosely into a "doll". The "dolls" were placed in a special alumi-

Table 1.—Standard laboratory germination and germination by two methods in cold soil of seed treated with fungicides by Wisconsin producers of hybrid seed corn and after re-treatment with Arasan dust (50 percent thiram).

Year tested and when seed was grown	Number samples tested	Standard laboratory germination	Cold soil germination and correlations between methods of test: Originally treated seed: Rolled towel method %	Walk-in refrig. method %	Average both methods %	Correlation coefficient	Re-treated seed: Rolled towel method %	Walk-in refrig. method %	Average both methods %	Correlation coefficient
1952										
grown 1951	79	96	68	62	65	+0.773**	94	90	92	+0.625**
1953										
grown 1952	370	96	84	78	81	+ .859**	94	90	92	+ .733**
grown 1951	38	95	68	70	69	+ .854**	87	87	87	+ .902**
grown 1950	22	94	42	44	43	+ .726**	80	81	80	+ .447*
grown 1949	11	94	46	40	43	+ .907**	72	76	74	+ .821**

* Exceeds 5% level of significance.
** Exceeds 1% level of significance.

num container which held them on end in a vertical position. The container was covered with plastic material held in place with a rubber band and placed in an ordinary electric refrigerator maintained at 48° to 50°F. for 10 days. Following the low temperature incubation the container with "dolls" was moved to a warm room (70° to 80°F.) and the germinations read usually 2 days later.

For the walk-in refrigerator tests, the kernels were planted in muck soil in aluminum pans kept in the large refrigerator for 10 days at a temperature of 48° to 50°F. The pans then were moved to a warm room where the germinations were read about 1 week later when the seedlings were in the 3- to 4-leaf stage of growth. The pans were watered when the seed was planted and as necessary after removal to the warm room.

All samples throughout the study were tested in three 50-kernel replications.

Fungicides Used by Seed Producers

The number of producers and the fungicides they used in the 1953 survey follow: Fifty-one, *Arasan* (dust or slurry); 18, *Orthocide* (dust); 7, *Semesan Jr.*; 2, *Barbak;* and 6, treatment not specified.

RESULTS

Seed Quality High

The quality of the seed tested was generally high when judged by the standard germinations which varied from 94 to 96% in the averages for the various crop-years (table 1). Only 20 (3.8%) of the 520 samples tested were rejected for "blue tag" certification because of lower than 90% germination.

Good Correlations Between Cold Test Methods

The similarity of results from both cold test methods is indicated by the high correlation coefficients given in table 1. The r values for the various crop-year comparisons all exceeded the 1% level of significance except for retreated seed from the 1950 crop, and here the 5% level was reached. With few exceptions the cold test reactions of individual samples were essentially the same by either method.

Differences Among Producers in Seed Treatment Effectiveness

That much of the seed had been poorly treated by the producers was indicated by the increases in germination of the retreated seed in the cold tests (table 1). In 1952 the average cold test germination of all samples treated by the producers was 65% compared wth 92% after retreatment. In 1953 the germinations of the producers' treated seed from the 1949, 1950, 1951, and 1952 crops were 43, 43, 69, and 81%, respectively, and for the retreated seed 74, 80, 87, and 92%, respectively. Thus, increases following retreatment of the seed were obtained in every comparison, ranging from a numerical increase of 11% for new seed grown in 1952, to 37% for 2-year old seed from the 1950 crop.

Table 2.—Distribution of hybrid seed corn producers in 1952 and 1953 into categories based on the cold test germination of their treated seed.

Cold test germination %	Number of producers in: 1952	1953
91–100	3 (17%)	27 (32%)
81–90	4 (22%)	22 (26%)
71–80	3 (17%)	19 (23%)
61–70	4 (22%)	9 (11%)
60 or lower	4* (22%)	7† (8%)

* Average germination, 36%.
† Average germination, 55%.

Differences among the producers in seed treating efficiency are indicated in table 2 in which the producers are grouped in categories based on the cold test germination of their seed. Here it is shown that in 1952, 17% of the producers were rated "excellent" (germination over 90%), 22% were "good" (81 to 90%), 17% "fair" (71 to 80%), 22% "poor" (61 to 70%), and 22% were "very poor" (germinations lower than 60%).

In 1953 a similar classification showed 32% of the producers in the "excellent" category, 26% were "good", 23% "fair", 11% "poor", and 8% "very poor". These data indicate a marked improvement among the producers in 1953. Reasons for this are discussed later.

Causes for Poor Treatments

Some common causes for poor seed treatments were apparent. These included use of wrong fungicides, inadequate dosages, and carelessness in treating.

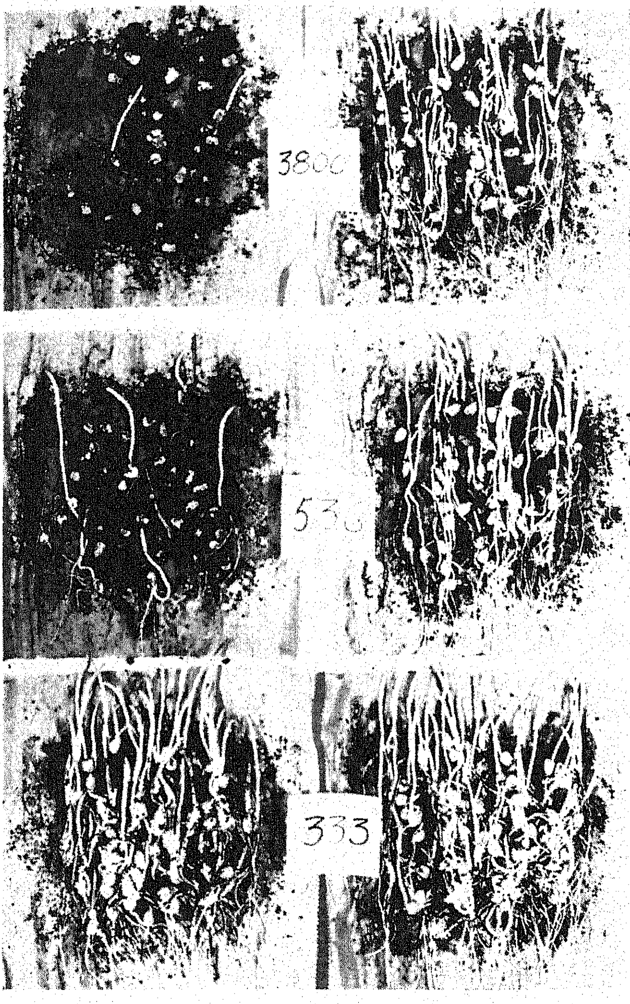

FIG. 1.—Excellent and also poor seed treatments of hybrid corn by different seed producers shown in rolled towel cold tests. Germination of the producers' treated seed are shown on the towels at the left, and for the seed after retreatment with *Arasan* at the right. Sample 3800 was from a producer who used *Semesan Jr.* with poor results typical of those who used old mercury-containing fungicides. Samples 536 and 333 were from producers who used *Arasan* (slurry). The original treatment of 536 was very poor while that of 333 was excellent. The producer of 536 failed to get enough of the fungicide on the kernels.

Wrong fungicides.—Nine of the 84 producers included in the 1953 survey still were using the old mercury dusts, *Semesan Jr.* or *Barbak.* These products are relatively ineffective for protection against soil fungi, and on old seed treated several years previously, become almost entirely impotent because of their volatile nature. In this survey, six of the producers who used either of these materials fell into the "very poor" class, one was "poor", and the remaining two were only "fair" in their efficiency (see figure 1).

Inadequate dosages.—There were some producers whose treatments invariably were poor, or mediocre, even though they used recommended fungicides. For one reason or another they simply failed to get sufficient fungicide on the kernels (see figure 1).

Carelessness.—A third cause for occasional poor results was carelessness on the part of the person doing the treating. This was illustrated in the case of a producer from whom 16 samples were found to be well seed-treated and 2 were poorly treated. This man was using an approved fungicide, had the best of treating equipment, and certainly the know-how for doing excellent treating, yet occasionally he had poorly treated seedlots.

Weakness in Old Seed Disclosed in Cold Tests

It has been found previously that the cold test germination of properly treated seed of high quality approximates its germination in standard tests. This again was shown in the present study but with exceptions that appeared to be generally correlated with age of seed. Data in table 1 show that the average standard germination of seed grown in 1949, 1950, 1951, and 1952 was respectively 94, 94, 95, and 96%, as compared with the cold test germinations of 74, 80, 87, and 92%, respectively. Thus, while the standard germinations remained essentially the same, the cold test germinations decreased steadily with age of the seed.

Differences among the carry-over seedlots varied greatly in reduced germinations in the cold tests. Many samples showed little or no decrease while in others the reductions were extreme (see figure 2). Conditions under which the seed was stored probably are an important factor contrib-

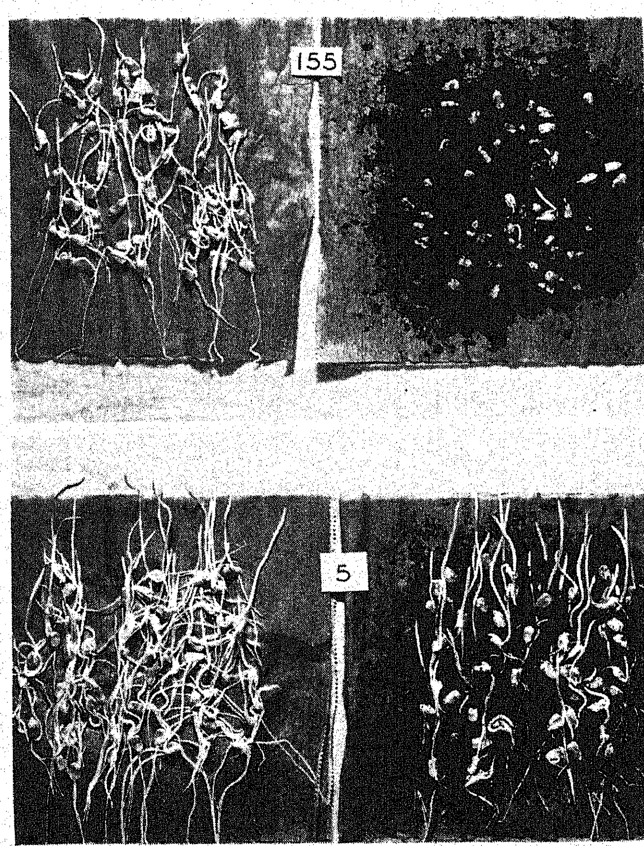

FIG. 2.—Weakness of old seed disclosed when retreated seed was cold tested. Both of these 2-year-old seedlots passed germination requirements for certification in the standard tests at room temperature (left), but in the cold test (right) the inferior seed quality of 155 was shown by its greatly reduced germination.

uting to the deterioration in seed quality strikingly expressed in the cold tests.

DISCUSSION AND CONCLUSIONS

This study demonstrated the efficiency of the rolled towel technique for corn cold tests. Similar results from the two methods used have been obtained more recently in other experiments and the towel technique has now entirely replaced the more cumbersome and expensive walk-in refrigerator method at the Wisconsin Station for all corn cold testing. This improved technique also has been adopted by many hybrid seed companies for routine tests and by manufacturers of seed protectants for screening fungicides in developmental programs.

It is shown that fungicides and treating equipment available on the market permit excellent corn seed treatment when the treating is properly done.

The reasons for the improvement in seed treatment noted in the second year of the survey are not completely known. Some of the improvement was due to a shift of producers from the poorer categories the first year to "good" and "excellent" classes the next year after being informed of the causes for their original poor results. A more important factor for the improvement might well be that in the second year the producers knew the survey was to be made, and many undoubtedly exercised greater care when treating their seed. In any case, most seed producers want information like that obtained in this study, and they usually are eager to correct any wrong situation.

The evidence in the present study that cold tests disclose weakness in old seedlots that do not show up in standard germination tests is of special interest to those concerned with seed corn certification. According to the present certification rules, the germination requirements are based on the standard room temperature tests. Most complaints of poor field stands of corn from certified seed received by the Wisconsin Seed Certification Service have been where old seed was planted. It would seem desirable to consider a change in the rules for certification to include cold testing, particularly for old seed, so that at least the worst of those found to be inferior are denied certification.

This would insure higher seed quality for the farmer who plants the seed and would be better for everyone concerned. The rolled towel cold test provides a laboratory method for making the required tests.

Notes

THE EFFECT OF INCREASED DAYLENGTHS ON THE PRODUCTION OF GREEN-HOUSE GROWN OATS[1]

THE production of several generations of small grain plants in one year is of major importance in a plant breeding program, especially where the backcross method is employed. A decrease in the time required from germination until maturity of a small grain plant would permit a more rapid development of new varieties.

Experiments have been conducted in the greenhouse at Iowa State College to determine the optimum temperature and photoperiod requirements for producing satisfactory oat plants in the shortest possible time. Four-inch pots, each containing 3 oat plants, were kept in 58° F. and in 70° F. greenhouses at the following photoperiod treatments: 9 hours, 9 hours plus 1 hour at midnight, 15 hours, 18 hours, and 24 hours of light. Supplemental light sources consisted of two 20-watt fluorescent bulbs, one white and one daylight. These lights were adequate to maintain plant growth but did not cause excessive heating of the chambers (3 by 3 by 4 feet) as would incandescent bulbs of a size necessary to maintain growth.[2] Plants were kept in the chambers under either complete darkness or supplemental light except from 8 a.m. to 5 p.m. when they were placed on benches in full daylight. Five oat varieties, Bond, Clintland, Mo 0-205, Simcoe, and Victorgrain, which when spring grown are classified as early, midseason, midseason, late, and very late in maturity, respectively, were used in this study. The number of days from planting of the seed until the heads emerged from the boot was determined for each variety-temperature-photoperiod combination. Plants not headed after 90 days were discarded.

The average number of days from planting until heading for each variety-photoperiod combination (18 plants) at 70° F. is presented in table 1. Oats grown at 58° F. required about 8 days longer to produce heads than those grown at the same photoperiod at 70° F. No heads were produced within 90 days by plants grown under the 9-hour day length, but a 9-hour photoperiod plus 1 hour of light in the middle of the dark period gave a semi-long day response. The shortest period from planting to heading for each of the varieties occurred when the photoperiod was from 18 to 24 hours. Although there was some shifting in the rank of the varieties with respect to the number of days required for the plants to head when grown at different photoperiods, the interaction was quite small. Allowing the normal 30 days from heading until the seed is ripe, a generation of Bond, Clintland, or Mo 0-205 varieties can be produced in about 75 to 80 days. Even the very late variety, Victorgrain, would mature in 85 days.

With a 24-hour photoperiod, using a fluorescent supplemental light source, and 70° F., it has been possible to grow four backcross generations of oats in one year at Iowa State College. The plants grown under these artificial conditions produce heads with 8 to 30 florets each, which is a sufficient number for backcrossing.

Table 1.—Number of days from planting to heading of five oat varieties grown at five different photoperiods in a 70° F. greenhouse, Ames, Iowa.

Varieties	Photoperiod				
	9 hours*	9 hour + 1 hour	15 hour	18 hour	24 hour
Bond	—	60	52	44	43
Clintland	—	58	47	43	42
Mo 0–205	—	58	54	48	48
Simcoe	—	65	59	52	51
Victorgrain	—	67	65	54	54

* None of the plants headed within 90 days after planting with the 9 hour photoperiod.

After the backcross seeds are harvested, the oat plants are removed to a cool chamber where they tiller profusely. When the tillers are in the first leaf stage, each pot is fertilized liberally with nitrogen and kept at a 14-hour photoperiod. This procedure gives a large number of F_2 seeds for selection purposes.—S. C. WIGGANS *and* K. J. FREY, *Assistant Professor of Botany and Farm Crops, and Associate Professor of Farm Crops, respectively, Iowa State College, Ames, Iowa.*

[1] Contribution from the Agronomy and the Botany and Plant Pathology Departments, Iowa State College, in cooperation with the Field Crops Research Branch, A.R.S., U.S.D.A. Journal Paper No. J-2735, of the Iowa Agr. Exp. Sta., Ames, Iowa. Projects 1139 and 1176. Received for publication March 23, 1955.

[2] Wiggans, S. C. and Shaw, R. H. Effect of fluorescent and incandescent light on temperatures in photoperiodic chambers. Iowa State Co. Jour. Sci. (in press).

A TECHNIQUE FOR COLLECTING PURE ALFALFA POLLEN[1]

SUFFICIENT pollen for large-scale analysis can be collected by direct means from various wind-pollinated plants, but from most insect-pollinated species this is nearly impossible. Pollen traps placed in the entrances of honey bee colonies may be used in some areas to collect large quantities of mixed pollens, which usually can be separated into the component species. However, with this method there is no control over the source of the pollen collected. The technique herein described enables the collection of adequate amounts of pollen from individual clones of alfalfa.

In 1952, cuttings of three clones of alfalfa were established in the greenhouse and set out in the spring in three plots each of which could be covered by a Lumite screen cage 11½ by 21½ by 6 feet. Each plot was planted with cuttings from one of the clones. When the plants were approaching full bloom, a well-developed nest of bumble bees was placed in each cage. Two of these nests were of *Bombus morrisoni* and one was of *B. occidentalis*. Several times each day the cages were visited and bumble bees with pollen loads captured in an insect net. They were then anesthetized and the pollen was removed. The bees appeared to suffer no ill effects, as pollen was removed from marked bees on several consecutive days.

Colonies of honey bees (*Apis mellifera* L.) were used to collect pollen in 1953. Pollen traps were placed on the

[1] Received March 12, 1955.

hive entrances to remove the pollen pellets from the legs of the bees as they entered, so that it was not necessary to catch individual bees. In only one cage was any pollen trapped, and while the quantity was smaller than in collections made from uncaged colonies, it was more than 3 times the amount collected from bumble bees on the same plot the previous season.

The clones chosen for this work were from a series observed by Pedersen and Bohart[2] to vary considerably in their attractiveness to pollen-collecting bumble bees. They found that this attractivness was associated with pollen sterility. There was a close relationship between the attractiveness and the amount of pollen obtained from each clone. From the most attractive clone 1.3 g. was collected by bumble bees and 4.8 g. by honey bees. The clone second in attractiveness yielded 0.87 g. from bumble bees and none from honey bees. No pollen at all was obtained from the unattractive clone in spite of the fact that no other pollen was available to the bees in the cages.

The essence of this technique is to have one plant increased into a number of plants by cuttings and have bees collect pollen from them under conditions that preclude its contamination from other sources. Pedersen and Bohart[3] pointed out that in small cages bumble bees present fewer maintenance problems than do honey bees. Furthermore, it appears that they are less sensitive to factors affecting the attractivness of alfalfa to pollen-collecting bees. On the other hand, the use of a pollen trap on a colony of honey bees reduces the amount of time spent in obtaining the pollen. The choice of bumble bees or honey bees would, therefore, depend on the amount of pollen desired and the time the experimenter is willing to spend.—M. D. LEVIN, *Entomology Research Branch, and* M. W. PEDERSEN, *Field Crops Research Branch, A.R.S., U.S.D.A. in cooperation with Utah Agr. Exp. Sta.*

[2] Pedersen, M. W., and Bohart, G. E. Factors responsible for the attractiveness of various clones of alfalfa to pollen-collecting bumble bees. Agron. Jour. 45:548–551. 1953.

[3] Pedersen, M. W., and Bohart, G. E. Using bumble bees in cages as pollinators for small seed plots. Agron. Jour. 42:608. 1950.

RESISTANCE TO RUST (*Puccinia sorghi*) IN CORN[1]

CORN rust, incited by *Puccinia sorghi* Schw., has increased in prevalence in the United States in recent years and is a threat to stabilized corn production. The lack of information on the genetics of resistance in the host and the genetics of virulence in the pathogen has prompted a comprehensive cooperative research project.[2] Within this project, the authors are charged with the responsibility of locating genes for resistance in corn and determining their mode of inheritance.

It is a common observation that many corn strains remain relatively rust free when exposed naturally to the fungus in the field. However, only a portion of these strains have expressed protoplasmic resistance when artificially inoculated in the seedling stage. On the other hand, strains expressing resistance in seedling evaluations have, so far, also expressed it as mature plants.

To date, 45 strains of corn have been located which possess protoplasmic resistance (chlorotic to necrotic flecks —0; or 1- pustule types) to one or more biotypes of the pathogen in greenhouse seedling inoculations. Many of these strains have been obtained from the North American corn belt, several from Central and South America,[3] and others from such widely separated areas as Ethiopia and Australia. They range from those in which resistance is expressed to a large number of fungus biotypes to others which resist only a few. Although these 45 strains appear to be different on the basis of their reaction to a group of fungus biotypes, it is anticipated that many will have common genes, in various combinations, for rust reaction.

The genes conditioning reaction to rust in the sources of protoplasmic resistance known to the authors are in the process of identification. Each gene is being transferred by backcrossing to several dent corn inbred lines. These will serve as a reservoir of resistant germ plasm and facilitate the breeding for resistance. Ultimately one inbred line with its set of sub-lines, each possessing a different rust resistance reaction conditioning gene, will be selected as a series of differential hosts for use in differentiating fungus genotypes and defining the objectives in breeding for resistance.

For maximum value and stability, such a series of differential hosts should embody, as near as possible, all genes for rust resistance. Therefore, the authors wish to bring their efforts to the attention of other corn workers interested in the problem so that additional sources of protoplasmic resistance may be added to those already accumulated. As the primary interest is in the rust reaction conditioning genes, such sources or suspected sources of resistance could be in various forms such as inbred lines, open pollinated varieties, or hybrid combinations. Information on the type of resistance and origin and history of the stocks would be helpful in accelerating the identification of the genes involved in rust resistance and the synthesis of the differential hosts.

The sources of resistance and derived lines would be available for distribution to all who are interested.—A. L. HOOKER, *Agent (Plant Pathologist), Field Crops Research Branch, A.R.S., U.S.D.A. and Department of Plant Pathology, University of Wisconsin, formerly Assistant Professor, Department of Botany and Plant Pathology, Iowa State College;* G. F. SPRAGUE, *Principal Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A. and Department of Agronomy, Iowa State College; and* W. A. RUSSELL, *Assistant Professor, Department of Agronomy, Iowa State College.*

[1] Contribution from the Field Crops Research Branch, A.R.S., U.S.D.A., in cooperation with the Wisconsin Agr. Exp. Sta., Madison, Wis., and the Iowa Agr. Exp. Sta., Ames, Iowa, Project No. 1140. Journal Paper No. J-2734.

[2] LeRoux, P. M., Dickson, J. G., Hooker, A. L., and Sprague, G. F. A genetic basis for rust reaction on corn. (Abs.) Phytopath. 44:496. 1954.

[3] LeRoux, P. M. Investigations on spore germination and host-pathogen reactions in corn rust incited by *Puccinia sorghi*. Ph.D. Thesis. University of Wisconsin Library. Madison, 1954.

Book Reviews

MANPOWER RESOURCES IN THE BIOLOGICAL SCIENCES

A Study Conducted Jointly by The National Science Foundation and the United States Department of Labor. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 53 pages, 1955. $0.40.

This is the fifth and final report in a series based on data collected by the National Scientific Register. The other reports concern physics, chemistry and chemical engineering, mathematics, and the earth sciences. The fields of specialization included in this report are agricultural sciences, animal sciences, microbiology, plant sciences, other specialties, and general biology. The agricultural sciences comprise forestry, animals, agronomy, horticulture, soil science, and range science.

Agricultural scientists comprise the largest group of biological scientists checked in this survey. More than 8,000 or 40% of the total number supplying information classified themselves in some branch of agricultural science. The scientists who carry on research, teaching, and other professional activities in all areas of biology (excluding graduate students) are estimated to number about 50,000 or less than 1/10 of 1% of the nation's labor force. Biological scientists are an older group than physical and earth scientists, whose professions have expanded more rapidly in recent years than most branches of biology. In 1951, the median age of biologists was 39, well above that for scientists in other fields. More than a fifth of the men biologists in the survey were members of military reserve organizations in 1951. The proportion of reservists was much higher in the younger age groups. In genetics, plant scientists, and bio-physics between 70 and 80% held Ph.D. degrees. In the agricultural sciences, however, scientists with bachelor's degrees only comprised the largest educational group, representing close to one-half of all the surveyed agricultural scientists. Teaching was the chief endeavor of the largest group of biological scientists (35%), followed by research (32%), and administration (18%).

Other areas of information on biological scientists include citizenship status, educational background, women biological scientists, and various aspects of employment such as professional income, type of employer, and field of employment. Seven tables and 6 charts are included in the text and 30 additional tables in the appendix.

Anyone concerned with the education of soil and crop scientists should find this publication useful. Comparisons of agronomy and soil science may be made with the field of biological science as a whole or with a specific biological science or with other fields of science covered by the four previous reports mentioned above. Administrators and educators in colleges and universities should find this useful as an aid in laying plans for the education of future biological scientists—C. L. W. SWANSON.

THE HOME GARDENING ENCYCLOPAEDIA

Published by Philosophical Library, Inc., New York. 368 pp. illus. 1955. $6.00.

From *Abelia* to *Zygopetalum* this useful volume contains prodigious amount of practical how-to-do-it information for the home gardener. Annual, biennial, and perennial flowers, shrubs, vegetables, and small fruits, and the various cultural practices for the numerous individual plants in each of these groups make up the contents of this book. It is remarkable for the simplicity and clarity of its style; and excellent half-tone figures and line drawings illustrate many of the practices described in the text. There are also numerous charts with descriptive information in tabular form on annuals, bulbs, fruit pruning, hedge plants, vegetable seed sowing, vegetable ailments, fungicide and insecticide recipes, and a host of other topics. Although this is a British publication, American readers will have no difficulty whatever with it. The last section of the book, which is a calendar of garden activities, is written to include the warmer latitudes; thus the book will be of great use to gardeners anywhere.

MANAGING THE FARM BUSINESS

By Raymond R. Beneke. New York, John Wiley & Sons, Inc. 464 pages. Illus. 1955. $3.96.

This book was written primarily for vocational agriculture students in secondary schools and students in junior colleges and agricultural institutes, but farm managers will also find this book helpful. Major management problems are discussed from the standpoint of the economic principles involved in decision making rather than a listing of cut and dried answers to the problems faced by farmers today.

Chapters 1 to 5 deal with the establishment of a farming enterprise, bringing out both the legal and economic problems faced there; chapters 6 to 12 discuss cropping systems and planning and management of various livestock enterprises; chapters 13 to 16 consider the economic problems of efficient use of machinery, labor, capital, and farm buildings; chapters 17 and 18 are concerned with marketing from the producer's viewpoint; and the last three chapters deal with record keeping and other economic factors.

The principles outlined in the book are basic to all types of farms and examples have been taken from many locations in the country. The numerous illustrations used throughout the text were taken from a wide range of research studies and farm situations. The author, associate professor of economics and sociology at the Iowa State College, states that, to be of most value, the book should be supplemented with physical and economic data from the extension service and other agencies in the area where the book is used.

A STATISTICAL STUDY OF LIVESTOCK PRODUCTION AND MARKETING

By Clifford Hildeth and F. G. Jarrett. New York, John Wiley & Sons, Inc. 156 pages. 1955. $4.50.

This is the fifteenth in a series of monographs sponsored by the Cowles Commission for Research in Economics, and written in cooperation with the former Bureau of Agricultural Economics of USDA and the agricultural economics research group of the University of Chicago. The main emphasis of the study was placed on the development, application and testing of methods that might prove effective in analyzing interrelated segments of economic activity. The authors tried various methods, recent and traditional, of problem formulation and statistical analysis in an important and promising practical setting. The livestock complex was chosen for the study because of its importance, the availability of data and the possibility of obtaining information from previous studies.

The report is broken down into eight sections: introduction, the economic model, the observations, estimated relations, the production relation, the farm decision relations, the demand relation, and prediction tests. A 20 page appendix lists in detail the steps involved in the computations used in the text.

Agronomic Affairs

MEETINGS

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WSA reports that membership is open to individuals and organizations interested in its objectives from all nations. Membership dues are $6 for 1955, which includes a subscription to the journal, WEEDS, to be the official publication of the society. K. P. BUCHHOLTZ, agronomy department, University of Wisconsin, is editor, and W. C. JACOB, University of Illinois, was named business manager of WEEDS.

All persons joining the WSA during calendar 1955 will become charter members, and a permanent constitution will be considered at the 1956 meeting. Those interested in membership may contact Dr. Jacob for an application.

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MADSON IS HONORED AT CALIFORNIA

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Dr. Millar retired in 1950 after 35 years on the Michigan State College faculty. In 1930 he was appointed head of the soil science department. He had previously been an agronomy instructor at Kansas State College.

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L. A. DEAN has returned to the USDA at Beltsville, Md., after serving during the past academic year as visiting professor at the North Carolina State College.

—A—

ALBERT W. MARSH, associate soil scientist at Oregon State College, Corvallis, is now at the U. S. Salinity Laboratory, Riverside, Calif., where he is in charge of the foreign trainee program for the laboratory. His assignment is for 1 year while A. D. AYERS, previously in charge, is in Egypt.

—A—

J. B. WEAVER, Jr., joined the University of Georgia agronomy department on July 1 where he is engaged in teaching and work in cotton genetics and variety testing. He received his Ph.D. degree in May from North Carolina State College.

—A—

GEORGE E. RITCHEY retired June 20 as agronomist in charge of the Suwanee Valley Experiment Station, Live Oak, Fla. His successor is H. W. LUNDY as associate agronomist in charge.

—A—

W. A. WHEELER has accepted an assignment as consultant in seed marketing in the USDA Agricultural Marketing Service at Washington, D. C.

—A—

DAVID RIRIE, formerly with the University of California, has accepted an appointment from the Church of Jesus Christ of Latter-Day Saints to supervise the development of a tract of peat land at the Latter-Day Saints College in Hamilton, New Zealand.

—A—

R. E. LUEBS has been engaged as soil scientist with the USDA at Lincoln, Nebr., since receiving the Ph.D. degree in soil fertility at Iowa State College, last December.

—A—

K. O. RACHIE has returned with his family to the University of Arizona after spending the past year in Iraq where he helped establish an agronomy department at Abu Ghraid Agricultural College.

—A—

MOYLE E. HARWARD, formerly assistant professor of agronomy at North Carolina State College, is now with the soil department at Oregon State College, Corvallis. His new position, assistant soil scientist and assistant professor of soils, involves research in soil chemistry and the fundamentals of soil fertility, and teaching graduate courses in these fields.

—A—

MERVIN D. HAGUE reported for active duty July 15 as a second lieutenant in the Air Force after receiving his M.S. degree at Kansas State College. After a 2-year tour of duty, he plans to return to Coon Rapids, Iowa, to do production research for the Garst and Thomas Hybrid Seed Corn Co.

—A—

J. A. KITTRICH, who received his Ph.D. in soils at the University of Wisconsin this summer, is now at the State College of Washington, Pullman, as assistant professor of soil chemistry in clay mineralogy.

—A—

NORMAN GAETZE, formerly of Oregon State College, is now at Purdue University as research assistant to W. H. DANIEL. He is working toward the Ph.D. in a turf management study.

—A—

O. CHARLES RUELKE, formerly research assistant in agronomy at the University of Wisconsin, is now assistant professor of agronomy at the University of Florida, teaching courses in crop ecology, pastures, and forage and cover crops. He also conducts an undergraduate agronomy Seminar, and is carrying on research work in forage production.

S. C. VANDECAVAYE, professor of agriculture at Idaho State College, has accepted a position in charge of soils work at New Mexico A and M.A. College, replacing H. E. DREGNE who will spend the next two years in West Pakistan. Dr. Vandecavaye, formerly of Washington State College, is a former president of the Soil Science Society of America.

CORRECTION

In the article, "Effects of Two Cycles of Recurrent Selection for Combining Ability in an Open-Pollinated Variety of Corn," by D. P. McGill and J. H. Lonnquist, *Agronomy Journal*, July 1955 issue (47:319–323), the equation on page 321 printed as follows:

$$T = \frac{s^2{}_{p1} - {}^2{}_{p2}}{\sqrt{V^2{}_{sp1}\, V^2{}_{sp2}}}$$

should read as follows:

$$T = \frac{s^2{}_{p1} - s^2{}_{p2}}{\sqrt{V_{s^2 p1}\, V_{s^2 p2}}}$$

In the same paragraph, $V^2{}_{sp} =$ should read $V_{s^2 p} = \ldots$

In column 1, table 2, of the same article, page 320, KLn should read KL_{II}.

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AGRONOMY JOURNAL

Volume 47 September 1955 Number 9

Photoperiodism in Rice: VII. Photoperiodic Response of Two Early Varieties of Rice[1]

Gadadhar Misra[2]

MAJOR benefits to agriculture from studies of photoperiodism have been achieved in the United States. Selection of adapted varieties, planting at optimum dates, and the storage of plant materials for suitable periods at proper temperatures are but a few examples of practices related to photoperiodism.

Beachell (2), Adair (1) and Jenkins (3) have reported on the effects of various day-lengths and dates of sowing on the flowering behavior of some American varieties of rice. Most of the research on photoperiodic response of rice has been reported from Japan, India, and Ceylon. From the results obtained by Kar and Adhikari (5), Misra (6, 7, 8, 9, 10, 11) and Sen (12) it appears that photoperiodic response of rice largely is dependent upon the variety. Much more research is needed to understand fully the mechanisms of flowering in the rice plant.

MATERIALS AND METHODS

This study was designed to determine the photoperiodic behavior of two early rice varieties, T.N. 32 (a selection from Baljati of Lucknow district) and T.A. 64 (a selection from Hansharaj of Unao district) of Uttar Pradesh. When seedlings of these varieties were 10, 20, 30, 40, and 50 days old, respectively, they were subjected to a 10-hour (8 A.M. to 6 P.M.) photoperiod for 1 month. In another experiment, seedlings of the same age were given the same short photoperiod treatment but prolonged until ear emergence. Each treatment consisted of 20 seedling plants. A control (normal photoperiod) was included for comparison.

Four seedlings per pot were planted outdoors in five replications in a randomized design. The 10-hour photoperiod was attained by keeping the pots in daylight from 8 A.M. to 6 P.M. and then removing them to a well-ventilated dark room for the remainder of the 24-hour cycle. The initial sowing was made on April 4, 1950.

Data were recorded on heading date, number of tillers per plant, plant yield, and the important components of yield, including number of panicles per plant, panicle length, grains per panicle, spikelets per panicle, percent seed set and weight per 1,000 grains.

EXPERIMENTAL RESULTS

The data from these studies are summarized in tables 1 and 2 and certain responses shown graphically in figures 1 and 2. Representative plants of the variety T.A. 64 are illustrated in figure 3. In general, both varieties gave very similar responses to photoperiod treatments and therefore the data in table 2 are based on the mean response for both varieties.

Time of Heading

The number of days required from sowing to head emergence of the main shoot under different short-day treatments is summarized in table 1 and shown in figures 1 and 3. In all cases, short photoperiods delayed emergence of the panicle. The delay in panicle emergence was directly related to the duration of treatment. For example, seedlings at 10-day age subjected to short photoperiod treatment until heading were delayed 13 days in comparison to the controls, while those given a 1-month treatment were delayed 9 days in heading. Seedlings more advanced in age when placed under short day were retarded successively less in heading. This relationship between age of seedlings prior to treatment and delay in heading was essentially linear for both varieties.

Tillering

The number of tillers per plant was determined at 20-day intervals during the ontogeny of the plant. When short-day treatments were given until heading, the number of tillers was increased when started with older seedlings. Although short-day treatments for 1-month duration did not produce as consistent results as with the longer duration, the general trends were the same. In all cases, 10-hour photoperiod reduced tiller development of seedlings exposed when 30 days or less in age. This apparent inhibitory effect of short-day on tiller development with young seedlings and lack

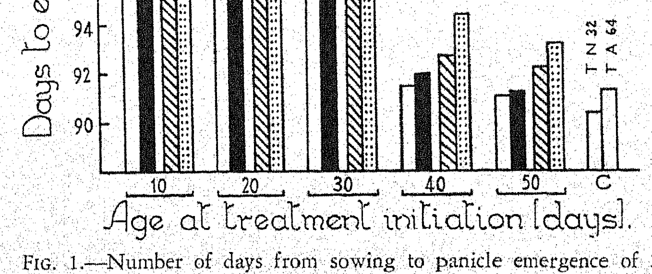

FIG. 1.—Number of days from sowing to panicle emergence of 2 early varieties of rice given short-day (10 hour) treatment when 10 to 50 days old for 1 month and for the duration until heading.

[1] This investigation was carried on in the Department of Botany, University of Allahabad, India. The writer expresses his deep gratitude to Prof. Shri Ranjan for his guidance and encouragement, to Mr. C. M. Bastia for his help in the preparation of the diagrams and photographs, to Dr. B. Samantarai for his valuable criticism, and to Dr. I. J. Johnson, Iowa State College, for his help in revising the manuscript. Received Jan. 5, 1954.

[2] Lecturer in Botany, Department of Botany, Ravenshaw College, Cuttack 3, India.

Table 1.—Effects of reduced photoperiod to 10 hours on number of days from sowing to panicle emergence of the main shoot in two early varieties of rice.

Age of seedlings at treatment initiation (days)	Number of days from sowing to panicle emergence							
	Treatment duration one month				Treatment duration until heading			
	T.N. 32	T.A. 64	Mean	Delay*	T.N. 32	T.A. 64	Mean	Delay*
10	99.2	99.5	99.4	8.6	103.3	104.6	104.0	13.1
20	97.8	97.1	97.5	6.6	99.3	102.5	100.9	10.1
30	96.0	96.9	96.4	5.6	99.0	98.4	98.7	7.9
40	91.4	92.7	92.1	1.2	91.4	94.4	93.2	2.3
50	91.0	92.2	91.6	0.8	91.2	93.2	92.2	1.4
Control†	90.4	91.3	90.8	—	90.4	91.3	90.8	—

S.E. of a treatment mean = 0.71 L.S.D. at 5% level = 2.0
S.E. of a variety mean = 1.00 L.S.D. at 5% level = 2.8

* Delay in days from heading date of control.
† Normal photoperiod for entire growth period.

Table 2.—Effects of reduced photoperiod to 10 hours on expression of characters associated with grain yield in rice. (Average values for varieties T.N. 32 and T.A. 64)

Age of seedlings at treatment initiation	Panicles per plant	Panicle length	Grains per panicle	Spikelets per panicle	Seed set	Grain weight
days	No.	cm.	No.	No.	%	g. per 1,000 grains
	Treatment duration for one month					
10	4.2	18.5	80.5	95.8	84.8	21.0
20	3.5	19.5	89.1	101.1	88.6	21.7
30	3.9	18.1	75.4	86.3	87.4	21.7
40	6.8	15.6	47.7	58.2	82.4	21.0
50	7.1	12.7	37.3	68.1	69.8	20.1
	Treatment duration to heading					
10	2.2	14.2	24.5	46.6	53.0	19.6
20	2.7	14.8	30.5	58.8	52.4	19.5
30	3.2	14.1	36.5	62.7	58.5	19.5
40	6.3	13.4	38.2	65.2	59.1	19.7
50	6.0	12.5	43.5	75.2	57.9	19.5
Control*	4.9	18.2	72.4	84.3	86.4	21.1

* Normal photoperiod for entire growth period.

of suppression on older seedlings was probably due to the fact that older seedlings had initiated tillers prior to treatment.

Grain Yield

Grain yield per plant is shown for both varieties and all photoperiod treatments in figure 2. Prolonged short-day treatment greatly reduced yields, especially when started with young plants. At progressively older seedling growth, reductions were progressively less. Exposure of rice seedlings to a 30-day short day had very little effect on grain yield, regardless of the age of seedling when treatments were begun.

Components of Yield

Because of the marked differential response of rice to duration of short photoperiod, measurements were made on several plant characters normally associated with the expression of final yield. Since both varieties responded in a similar manner, only the average values are presented in table 2. The data in table 2 show that the number of panicles per plant was reduced when short-day treatment was given to seedlings 30 days or less in age. The reduction in number of panicles per plant was especially marked when the treatment duration on younger seedlings was continued until heading. In contrast, short-day treatment to 40 and 50 day-old seedlings for either 1 month or until heading greatly increased panicle formation.

Short photoperiod had little effect on panicle length when 10- to 30-day old seedlings were exposed for 1 month. On older seedlings, short day reduced panicle length. Under prolonged short-day exposure, panicle length was reduced for all ages of seedlings.

The number of grains per panicle was greatly reduced when short-day exposure for 1 month was given to 40 and 50-day old seedlings and in all cases when the exposure was prolonged to heading. With the longer exposure, the reduction in grains per panicle was greatest when given to the younger seedlings.

The effects of short photoperiod on number of spikelets per panicle were similar in trend but somewhat less in extent than on the number of grains per panicle. Percent seed set, based on the grains per panicle and spikelets per panicle, clearly show the injurious effects of short-day photoperiod for the longer duration and for 50-day old seedlings exposed for 1 month. Grain plumpness was only slightly reduced as a result of the long exposure to short-day length.

DISCUSSION

Reduction in grain yield per plant apparently is due to a combination of several characters adversely affected in a cumulative manner by reduced day-length. The extent of response is conditioned both by age of seedling plants as well as duration of treatment. Delay in heading date as a response to short photoperiod was similar to that obtained with 4 other varieties of early rice of the State of Uttar Pradesh (7) and 2 summer varieties of the State of Bengal (13). Kar (4) and Sircar and Parija (14) failed to obtain a delay in heading in the summer (aus) varieties studied by them. It would thus appear that the effects of short photoperiod differ among varieties. The photoperiodic response of these two early varieties was somewhat similar to that of midseason varieties (7).

SUMMARY

The effects of short photoperiod were studied on two early varieties of rice, T.N. 32 and T.A. 64. Short day lengths were given to 10, 20, 30, 40, and 50-day old seedlings for 1 month in one series of experiments and until the time of panicle emergence in another series.

Short photoperiods delayed the first panicle emergence in both varieties in a similar manner. Retarded heading was greatest when the treatment was applied to young seedlings 10 days old and was progressively less with older seedlings 20 to 50 days old in essentially a linear manner. Delay in heading was greater when short photoperiod extended until panicle emergence.

Reduced day-length adversely affected yield per plant largely through the cumulative effects on number of panicles per plant, panicle length, grains per panicle, spikelets per panicle, and percent seed set. Marked reduction in plant yield was obtained only when short day length was applied to young seedlings for the entire duration of plant growth up to panicle emergence. Yield reduction was progressively less when seedlings were more advanced in age prior to treatment.

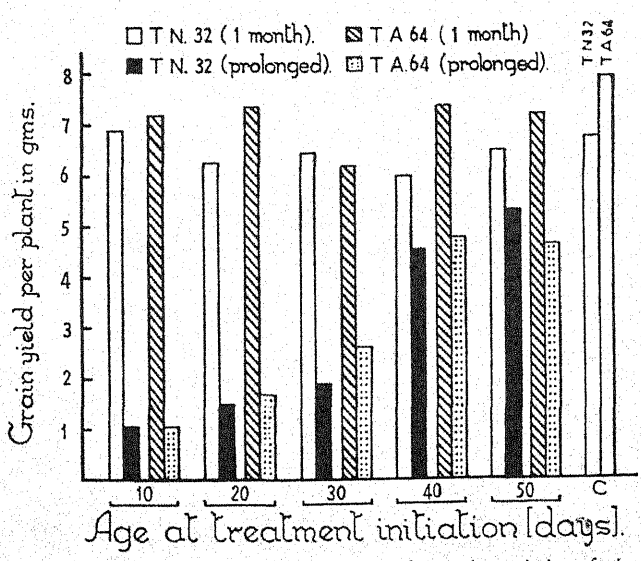

FIG. 2.—Grain yield in grams per plant of 2 early varieties of rice given short-day (10 hour) treatment when 10 to 50 days old for 1 month and for the duration until heading.

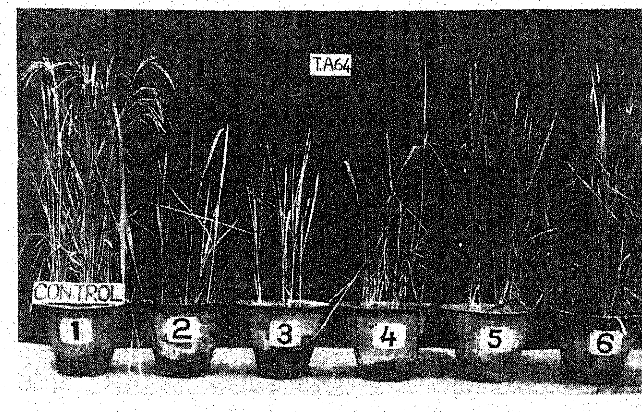

FIG. 3.—Growth characteristics and panicle development of early rice variety T.A. 64 at normal photoperiod (control) in comparison wth 10 hour photoperiod until heading given to seedlings at different ages from 10 days (pot 2) to 50 days (pot 6).

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X-Ray Breeding of Peanuts (*Arachis hypogaea* L.)[1]

Walton C. Gregory[2]

THE successful production of useful mutations in small grains has been reported by Gustafsson (4), Shebeski and Lawrence (11), Mac Key (10), and Frey (3). Humphrey (8) has reported similar results with soybeans. Andersson and Olsson (1) have described an outstandingly improved variety selected from an X-irradiated population of white mustard, a cross-pollinating species. Freisleben and Lein (2), Konzak (9), Mac Key (10), Frey (3), and Cooper and Gregory (unpublished) have shown that, by means of irradiation, it is possible to produce strains of plants with greater resistance to several plant diseases. In the lower plants, increased yields of fermentation products have been reported by Hollaender (6) and by Hollaender *et al.* (7).

In these reports (excepting Hollaender (6)) the improved yields obtained from irradiated stocks have been associated with individual mutations which through specialized reactions with the environment have made possible greater gains. Thus for example Gustafsson (5) reported that certain of the erectoides mutants of barley, because of their stiff straw, permitted higher nitrogen fertilization and thus higher yields. Frey (3) attributed the large differences in yields among control and irradiated progenies of oats to differences in stem rust resistance rather than to the mutation of yield genes. Although quantitatively changed characters have been measured, the variation in otherwise normal-appearing members of irradiated populations has not been studied *per se* nor from the standpoint of the possible polygenic character of that variation.

In his work with the ultra violet radiation of *Penicillium notatum* (and *Aspergillus terreus*) Hollaender (6) pointed out that there seemed to be little if any relation between morphological mutation and change in penicillin production; he stated, "as a matter of fact the normal-appearing cultures have a tendency to give the higher yields." Hollaender also indirectly suggested a polygenic control of increased fermentation products in his discussion of the occurrence of the much higher frequency of mutants with low production compared to the frequency of mutants with high production, the hypothesis being that a single change can block an enzyme sequence reaction while several changes would be required to augment production.

In the present experiment with peanuts, Gregory *et al.* (unpublished) have shown that a continuous "spectrum" of deviation from normal exists within mutants in populations of plants following irradiation with X-rays. The most plausible explanation of this graded expression of the same mutation in different X_1 families of self-pollinating plants is that the differences are due to modifying effects of the background genotype. This reasoning has led to the hypothesis that the normal-appearing members of irradiated populations may be variously mutated with a large number of small individually inconsequential changes which, in the whole, form a sound basis for artificial and natural selection.

In the results presented here two experiments designed for a preliminary exploration of this hypothesis have been reported: *(1)* to estimate the total genetic variance and the effect of selection in a quantitative character (yield) among the progenies of randomly selected normal-appearing plants, and *(2)* to measure the performance of normal-appearing plants of greater than normal vegetative vigor from the same population.

MATERIALS AND METHODS

The study reported here was conducted with a single uniform variety of Virginia Bunch peanuts. The variety had its origin in a single plant selection made by P. H. Kime in 1932. Farrior[3] conducted a study on peanuts wherein a large number of individual plants from several varieties was selected and tested for yielding ability. By comparing a pool of the higher yielding plants with a pool of the lower yielding plants within variety, Farrior concluded that mass selection for yield was without effect in Virginia peanuts. Earlier, Steinbauer *et al.* (12) conducted a similar study with similar results. Self-pollination is the rule in cultivated peanuts; and in the variety and area used in this study, it can be taken as occurring almost without exception.

In February 1949 four lots of peanuts were given four different preliminary treatments with 2,500, 5,000, 10,000, and 20,000r units of X-rays. These irradiations were carried out by the personnel of the Biological Laboratories, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Eight replicates of 16 seeds each and 8 replicates of 13 seeds each of every treatment and of untreated controls were planted in randomized complete blocks in 2 greenhouse benches, and data were taken on seedling survival. Survival in percent of seeds planted was as follows 54 days after seeding: control, 88.8; 2,500r, 87.5; 5,000r, 89.2; 10,000r, 60.3; and 20,000r, 30.6. These data were then used to determine the final dose for the experiment. Assuming that the mutation frequency would increase with dose up to the LD 50, it could be seen that the maximum number of mutations should be obtained with a dose between 10,000 and 20,000r. Thereupon 50 pounds of peanuts were irradiated with X-rays at 10,000r and 50 pounds between 15,000 and 20,000r.

The final treatments given and the approximate number of seeds in each treatment are given in table 1. After treatment each lot was planted in the conventional way. Untreated peanuts of the same variety were planted in the same field as a control.

When peanut seeds are treated with X-rays, the seedlings vary in their reaction to the irradiation in a manner similar to that of other organisms. After a certain dose is reached, a few seedlings die, still more are severely injured, and some are virtually normal

Table 1.—Radiation treatments (X-rays) of field planted peanut seeds 1949.*

No. of seed	Dose
37,500	10,000r ±10%
12,500	16,000r ±15%
12,500	17,500r ±15%
12,500	18,500r ±15%
75,000 = Total Seeds	

* Moisture content of the seeds = 8%.

[1] Contribution from the Agronomy Department, North Carolina Agr. Exp. Sta., Raleigh, N. C. Published with the approval of the Director of Research as Paper No. 622 of the Journal Series. Received Feb. 28, 1955.

[2] Professor of Agronomy, North Carolina State College. This work was supported by the U. S. Atomic Energy Commission as part of Contract AT-(40-1)-265.

[3] Farrior, J. W. The improvement of Virginia-type peanuts by mass selection. (Unpublished thesis) North Carolina State College, 1941.

Table 2.—Mean squares for progenies in sets for X_1 Classes A, B, and C shown with their appropriate errors. Yield in dry weight of fruits.

Source of variation	Degrees freedom	Mean squares	F
A progenies in sets	176	57,239	3.18
B progenies in sets	176	52,194	2.63
C progenies in sets	176	28,493	1.42
Error A	352	17,993	
Error B	352	19,825	
Error C	352	20,093	

Table 3.—X_1 class means and estimated genetic variances among progenies (1951).

X_1 class	Means (gs.)	Estimated σ^2g
A	747.00	13,082
B	746.95	10,790
C	833.49	2,801

in appearance. A portion of the 18,500r treatment was classified as to X_1 injury. The severely injured X_1 seedlings were given the symbol A, the normal X_1 seedlings were designated as B, while control seedlings were called C. Finally 1,118 A plants, 893 B plants and 1,200 C plants were classified. The A, B, and C symbols have been retained throughout the experiment. These plants were harvested individually and provided the material for the present experiments. The remaining X_1 plants were used for other purposes to be reported elsewhere.

Seeds from each A and B plant were planted in a progeny row in 1950. Each plant in the progeny rows of A and B was classified according to type and degree of mutation. There were 899 "A" progenies and 871 "B" progenies, a total of 84,213 X_2 plants.

Seeds of each X_2 mutant plant and of not less than two "normal" plants per X_2 progeny were planted in progeny rows in 1951. From a total of 13,441 X_2 plants *ca.* 250,000 X_3 plants were grown. Approximately 132,000 of these received detailed phenotypic classification.[1]

In 1951, the experiment designed to estimate the genetic variances in yield among progenies of normal-appearing X_2 plants from X_1A, X_1B, and control was conducted. A progeny of a normal-appearing plant from each of 192 randomly chosen X_2 families of the X_1A group, a similar selection from each of 192 X_2 families of the X_1B group, and progenies of a random sample of 192 control plants were used to make the estimates. The basic design of the experiment was as follows: Twelve each of randomly selected progenies of X_1A, X_1B, and control families were planted to randomly arranged blocks of A, B, and C respectively in a set. Once assigned to a set, a group of progenies remained associated in the same set in all replications. The progenies were randomized within blocks, and blocks A, B, and C fell in random positions in sets. The whole, 192 each of A, B, and C fell into 16 sets which were randomized in each replication. There were 3 replications at 1 location with single row plots 3 by 18 feet. This trial was designated as "1951 σ^2g".

In 1952 the effect of selection in the X_3 was estimated in the X_4 generation where the 10 highest yielding progenies from the 1951 experiment were compared wth 10 progenies from among the 15 to 20 lowest yielding progenies from each of the classes X_1A, X_1B, and C. This experiment was called the "σ^2g Selection Test." The high group was replicated 7 times, the low group 4 times. Plot size was 3 by 60 feet in single rows.

Also in 1952, the experiment designed to measure the yield performance of normal-appearing plants of greater than normal vigor was carried out. In this experiment the only criteria used for choosing entries were normality of appearance and exceptional vegetative vigor. Thus, in a sense this experiment served to measure an extension of the class "normal", which might otherwise have been missed in a random selection. This experiment designated as the "X_4YT" was conducted with individual X_3 plant progenies in the X_4 generation. There were a total of 48 completely randomized entries, including control in 4 replications at 1 location. Plots were 3 by 18 feet in single rows.

The yields were measured in dry weight of fruits in each experiment. The weights were recorded in grams per plot for the "1951 σ^2g" and the "X_4YT" experiments, and in pounds per plot for the 1952 "σ^2g Selection Test."

Appropriate analyses of variance were made on each experiment and the total genetic variance estimated in the 1951 σ^2g by $\frac{\sigma^2p - \sigma^2e}{k}$, where σ^2p = the mean square for progenies A, B, or C in sets, σ^2e = the mean square for error A, B, or C in sets, and k = the number of replications. Additional yield trials were conducted in 1953 and in 1954 to confirm the results obtained from selection in 1951 and in 1952.

RESULTS

The results of the "1951 σ^2g" experiment are given in tables 2 and 3. In table 2 the pertinent mean squares from the analysis of variance of the 1951 σ^2g are given. Note the uniformity of the errors of A, B, and C on which the valid comparison of the A, B, and C progenies so strongly rests.

Table 3 shows the X_3 means of classes A, B, and C and the estimated genetic variances (σ^2g) arising from progeny to progeny differences within each X_1 class. It is important to point out that the estimated genetic variance for control is significant. The difference between the means of A and B is not significant; nor is the difference between their variances significant. The differences between A and C and between B and C are highly significant in both means and variances.

In order to determine whether or not effective selection for increased production could be made in these 3 populations, the 10 highest yielding entries of A, B, and C were selected and compared with each other and with similarly

Table 4.—The mean yields of dry fruits of the highest yielding 10 progenies and 10 progenies from among the lowest 15 to 20 progenies in 3 classes of plants, X_1 A, X_1 B, and C from the 1951 σ^2g experiment.

	Average X_3 yield of dry fruits (1951)					
	High group (g.)			Low group (g.)		
	A	B	C	A	B	C
	1117.3	1064.3	1112.3	267.7	361.3	511.0
	1064.3	1033.0	1078.0	339.3	390.0	611.3
	1052.3	1029.0	1067.0	348.7	478.7	639.3
	1015.0	1023.0	1023.7	387.0	482.3	648.3
	1013.0	1002.3	1018.3	392.7	502.7	648.7
	1000.7	993.7	1017.3	408.7	524.3	652.3
	997.7	984.3	1007.0	471.0	529.0	654.0
	985.3	981.0	1007.0	506.7	535.0	659.0
	966.3	971.0	1000.3	508.7	554.0	661.7
	966.0	967.0	993.3	538.0	554.3	674.0
Means	1017.8	1004.9	1032.4	417.3	491.2	636.0

[1] Acknowledgement: This report is a part of a large project carried out by many people. These persons, some of whom will publish their contributions independently, are: R. L. Bernard, W. E. Cooper, J. M. Eason, R. O. Hammons, Astor Perry, Ben W. Smith, and John A. Yarbrough. It is a pleasure to acknowledge the help of these men in the present study. R. E. Comstock, Department of Experimental Statistics, North Carolina State College, gave unsparingly of his time and advice on the statistical analyses and estimates of genetic variance.

selected lowest yielding progenies in the "σ^2g Selection Test." Table 4 gives the yield values in grams per plot of these high-low selections for the year (1951) in which the selections were made.

Table 5 gives the results of the σ^2g selection test (1952) in mean pounds per plot. It can be seen from table 5 that the A-high, B-high, C-high, and C-low means were virtually identical. The A-low and B-low groups were highly significantly different from the high groups and the C-low group and very similar to each other. From the 1952 data presented here, there seemed to be little reason to suspect that any of the high lines of A, B, or C were outstanding. That this did not prove to be the case is shown in line two of table 7.

In the X_2 and X_3 populations, the phenotypic variability with regard to vegetative vigor was extraordinary. In addition to the dwarfs and the steriles, the curled, the maimed, and the normals, there occurred with moderate frequency in the irradiated populations a number of normals which were of greater size and vigor than control. (For an illustration of one of these vegetatively vigorous normals after six generations of inbreeding compared to control, see figure 1.)

In table 6, the 10 highest yielding vigorous normals and their mean are given in comparison with the 10 lowest yielding and their mean, the mean of the trial, and the mean of control from the X_4 YT experiment.

In order to substantiate the inference that these high yielding vigorous normals were superior to control in yield as well as in vegetative vigor, yield trials were conducted during 1953 and1954.[5]

Of these lines, several have survived in the selections following these evaluations. The relative performance of the best lines with respect to each other and two leading commercial varieties released by the North Carolina Agricultural Experiment Station are shown in table 7.

Table 5.—The mean yields of dry fruits of the highest yielding 10 progenies and 10 progenies from among the lowest 15 to 20 progenies in 3 classes of plants, X_1 A, X_1 B, and C from the 1951 σ^2g experiment in 1952.

	High group (7 reps.)			Low group (4 reps.)		
	A	B	C	A	B	C
	12.54	11.75	12.21	8.06	10.00	12.50
	11.86	12.50	12.21	9.06	9.38	12.37
	12.14	12.32	13.00	9.62	9.19	12.88
	11.93	12.25	12.71	10.06	9.81	12.25
	12.00	12.50	12.68	9.12	9.38	12.37
	12.39	12.89	11.64	9.50	10.81	11.75
	12.71	12.89	12.50	10.87	11.12	12.81
	12.18	12.14	10.93	8.38	8.50	12.75
	10.60	11.71	12.86	10.44	11.44	10.81
	11.14	10.96	11.32	10.19	10.06	12.88
Means	11.95	12.19	12.20	9.53	9.97	12.34

Table 6.—X_4 YT, mean yields of the 10 highest and 10 lowest progenies 1952. Dry weight of fruits, grams per plot.*

	High group	All 48 entries	Control	Low group
	1880.0	——	——	636.0
	1862.5	——	——	806.5
	1858.7	——	——	1038.7
	1826.7	——	——	1063.2
	1778.2	——	——	1094.0
	1777.7	——	——	1128.0
	1678.5	——	——	1248.2
	1709.5	——	——	1268.7
	1645.2	——	——	1289.0
	1644.7	——	——	1306.5
Means	1775.2	1478.0	1372.5	1088.8

* Differences among progeny means highly significant.

Table 7.—Yields of the highest single line from the 10 X_4 YT, 10 A+B, 10 Control, compared to 2 check varieties in 10-replicate trials at 2 locations in 1953.

Source	Variety	Yield (lb. A.) Mean of two locations
Irradiated	X_4 YT	2804
	A+B	2801
Non-Irradiated	Control	2671
	NC-1*	2568
	NC-2*	2526
	LSD 0.05	158

* Recently released varieties of peanuts in North Carolina. In 1954 in 21 trials in 8 counties NC-2 averaged 15% higher yields and 25% higher dollar value/acre than the farm varieties with which it was compared.

DISCUSSION

The data presented here suggest that the use of ionizing radiations may not only be valuable in the production of specific changes such as disease reaction specificity in plants, but may be of general breeding value in agronomic programs. This is further brought out by the almost unbelievable variety of plant forms and reactions observed.

This same experience, however, would suggest caution in taking too liberally the suggestion that specific changes in already adapted varieties may be induced without affecting the background genotype in adaptability.

In evaluating the relative performance of the superior mutants reported here to that of the control, it should be borne in mind that this control is itself a highly selected, highly adapted commercial stock which has been used for years as the standard against which new varieties must compete. The failure of the two new varieties (which will on the average out-perform the control stock) to equal the control in the experiment reported in table 7 illustrates how difficult it is to make definite statements concerning superiority.

The experiments reported here do not prove that multigene differences of small magnitude are responsible for the quantitative variation reported. The variation measured was inter family variation and goes back to X_1 plant differences in its origin. Furthermore, in order to get a more accurate evaluation of the hypothesis that the quantitative variation is of polygenic nature, inter-plant crosses within families with similar measurements and analyses will be required. Nevertheless, the normality of the plants measured, taken together with the multi-mutated character of their X_2 and

[5] 1954 trials destroyed by Hurricane Hazel, Oct. 15, 1954.

X_3 sibs suggests the possibility of more than one small genic change in the normals, the genetic variation of which equaled four times that of the control in the character measured. It has been shown that the plant expression "normal" or in genetic terminology "wild type" may result from many different induced genotypes and that these have been exploited successfully by selection for the agronomic improvement of the plant. This is extraordinary in the sense that the broad genetic base for "wild type" in natural populations has been generally considered to have resulted from the effects of selection. The fact that there have been obtained in the inbred plants used in this study, simultaneous and numerous mutations to only normal suggests a greater adaptability of the organism than has heretofore been supposed; this may be of considerable significance in the better understanding of the evolution of self-pollinated plants, or for that matter, of evolution generally.

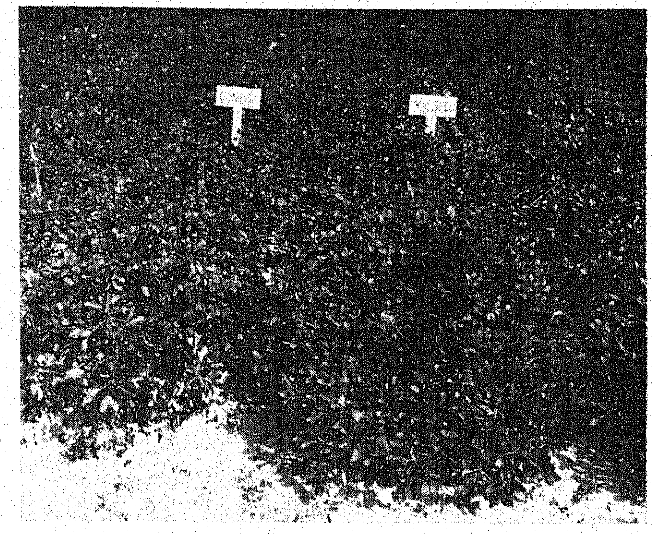

FIG. 1.—Vigorous X-ray normal (right) compared to untreated control peanuts (left) six generations after treatment, 1954.

SUMMARY

The amounts of genetic variation in a quantitative character, yield of dried fruits, have been estimated in progenies of X-irradiated peanuts. The total genetic variance was measured in X_2 plant progenies in the X_3 generation and in terms of progeny to progeny differences. Each progeny traced to an individual X_2 family. Each family traced to a single seed which received the irradiation treatment.

The estimates of genetic variation were made on normal plants only, 1 sample of which was randomly chosen from 384 different X_2 families. An additional sample consisting of 48 X_3 plant progenies was selected from normal but vegetatively vigorous mutants.

The total genetic variance among the randomly chosen irradiated normals was four times that measured in control progenies. Several high yielding mutants were recovered from the populations studied.

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Dormancy in Cotton Seed[1]

Basil G. Christidis[2]

IT IS a matter of common experience that ordinary seed viability tests, conducted soon after harvest, are not always reliable. In some species of plants, seeds need to go through a resting period known as primary dormancy before they will germinate (9). Germination under unfavorable conditions of light, temperature, moisture, or aeration, may also throw seeds into dormancy, so that they will not germinate when exposed later to proper conditions. This is a secondary type of dormancy and a review of the literature involved, with some facts and theories on the development, continuation, and breaking of secondary dormancy, was given by Thornton (24, 25) and Bibbey (2).

Delayed germination may be associated with structure of the seed coats (8, 19, 20, 23). Moreover, some plants show a special (epicotyl) dormancy which may be overcome by exposing them to temperatures between 5° and 10°C. after the formation of the roots (1). A detailed account of dormancy in seeds was given by Crocker (10) and Crocker and Barton (11).

The period of primary dormancy in wheat, oats, barley, or rye varies between 1 and 2½ months (18). Its length depends on stage of ripeness of the seed, temperature of storage, winter or spring habit of the plants and the variety used. Several other workers (13, 12, 7, 14, 4, 21) studied dormancy in cereals and obtained similar results. According to Brown, *et al.* (3), dormancy is a varietal characteristic, but moisture, as well as temperature, is of importance in maintaining dormancy (freshly harvested seed of oats and barley, kept at about 2°C. in a relatively high humidity, maintained dormancy for a period of 3 years).

In the case of cotton, seeds from bolls immediately after dehiscence also go through a period of dormancy and germinate poorly unless dried and stored for a few weeks (22). Upland varieties did not differ in this respect whereas the sea-island strain tested showed practically no dormancy. Further evidence of varietal differences in dormancy has been obtained in later experiments, which also indicated that with seed coats removed, there was no tendency for dormancy (23). In Arizona, evidence of dormancy, as judged by the viability test, existed only for 21 to 30 days after dehiscence with Upland varieties. In American-Egyptian varieties, differences were small and insignificant (15).

The present study was designed to provide further evidence on the importance and practical consequences of dormancy in cotton seeds. It was suggested by actual difficulties faced in Greece while applying a seed propagation project. Certain seed, known to be of good quality, germinated poorly when tested in November; three months later, however, the same seed proved to possess an excellent viability.

MATERIAL AND METHODS

In 1948, a variety test of the "balanced incomplete blocks" design, with 25 cotton varieties and plots receiving light or normal irrigation, had been carried out at the Hellenic Cotton Research Institute. Three of these varieties, known as 2x, 2Γ and 53Δ respectively (5) were chosen for studying dormancy. The first two are *Gossypium hirsutum* types produced in Greece by selection, whereas the third was bred from a cross between *G. hirsutum* and Egyptian (*G. barbadense*) cotton. For each variety or kind of irrigation, three pickings were made: the first (A) included bolls opening from Sept. 8 to 15, the second (B), those opening from Oct. 1 to 7, and the third (C), from Oct. 22 to 29. Thus the total number of different seed groups were 18 (3 varieties × 2 irrigations × 3 dates of picking); to minimize effects of soil heterogeneity, bolls were obtained from all six plots available for the same treatment. After every picking, the seed cotton was ginned in each group and the resulting seed stored for further study.

From the above 18 seed groups at certain intervals, representative samples were taken for germination tests. Six such tests were made in all: the first three, 3 days after the day of each picking (i.e. on Sept. 18, Oct. 10 and Nov. 1, 1948), and the remaining three on Nov. 22, 1948, Jan. 3 and April 2, 1949 respectively. All tests were made in an electric Copenhagen-type germinator with automatic temperature control. Eight replications were used for the first test, 6 for the second, and 5 for the remaining ones with samples of 50 seeds each. The temperature in the germinator was kept at about 30°C. with the usual technique, as decribed by Christidis and Harrison (6). To avoid any positional effect in the germinator, the arrangement of the samples was made according to a split-plot design, where the main samples were varieties × irrigation, and the sub-samples dates of picking.

In addition to germination percentage, rapidity in sprouting also was determined by estimating for each sample the mean number of hours needed for germination. This constitutes a new approach for detecting any delaying effect of dormancy on the germination of cotton seed. Moreover, in order to test whether differences in germination would be of any practical consequence to the succeeding crop (in 1949), a field test also was arranged with the 18 seed groups using a split-plot design with 6 replications of 3-row plots.

RESULTS

The data on germination obtained in all six tests are given in table 1. Since irrigation, or any of its interactions, in no case had any significant effect on the rate of germination, the data in table 1 are means for light or normal irrigation. Because the interaction of variety × date of picking reached the level of statistical significance only once (and then because variety 53Δ gave abnormal results) only data based on averages are presented in figure 1.

Data on time of sprouting are presented in table 2 for plots given light or normal irrigation.

Since testing conditions can never be entirely the same in different tests, the effect of "time of storage after boll opening", as shown in successive tests, is irrevocably confounded with "testing conditions". In the case of rate of germination, the data appear rather uniform except of those for the Jan. 1 test, which have been omitted in figure 1. Regarding time of sprouting, however, the data seem more sensitive. Accordingly, in each test and for every variety, quantities $\frac{100(C-A)}{A}$, $\frac{100(B-A)}{A}$, and $\frac{100(C-B)}{B}$ were worked out and the result (averaging differences for all three varieties, or the above quantities for every variety), is illustrated in figure 2.

The data obtained from the field test in 1949 are not given in this paper. The results showed conclusively that seeds from various pickings (A, B or C) had no effect on either yield of the following crop, lint length, earliness in maturity or ginning out-turn.

[1] Paper communicated to the 8th International Congress of Botany (Section of Agricultural Botany), Paris, July 2-14, 1954. Received Feb. 24, 1955.

[2] Cotton Research Institute, Sindos, Greece.

Table 1.—Germination percentage in successive tests of varieties of cotton at three dates of boll opening, Sindos, Greece.

Seed groups		Date of test 1948 Sept. 18	Oct. 10	Nov. 1	Nov. 22	1949 Jan. 3	Apr. 2
2 χ	A	80.4	92.8	93.0	93.8	83.4	96.0
	B	——	73.7	80.8	91.8	73.0	94.6
	C	——	——	70.6	81.4	77.6	91.2
	Mean	80.4	88.3	81.5	89.0	78.0	93.9
2Γ	A	71.8	91.8	94.8	96.8	78.4	95.8
	B	——	69.0	85.4	96.0	71.8	94.0
	C	——	——	75.8	88.8	87.6	89.8
	Mean	71.8	80.4	85.3	93.9	79.3	93.2
53 Δ	A	65.6	86.3	90.2	93.6	77.4	89.6
	B	——	62.2	79.4	92.2	65.0	86.8
	C	——	——	80.8	81.4	74.6	84.2
	Mean	65.6	74.3	83.5	89.1	72.3	86.9
	A	72.6	90.3	92.7	94.7	79.7	93.8
	B	——	68.2	81.9	93.3	69.9	91.8
	C	——	——	75.9	83.9	79.9	88.4
General mean		72.6	79.3	83.5	90.6	76.5	91.3
L.S.D.:							
Varieties		7.9	5.7	n.s.	2.8	5.4	2.7
A, B, C,		——	3.3	2.8	2.0	5.3	2.5
Interaction		——	n.s.	4.9	n.s.	n.s.	n.s.

DISCUSSION

If by dormancy we mean a temporary inability of, or delay in germination, the data from this study leave little doubt that such definitely occurs in the cotton seed. Regardless of the date of boll dehiscence or the variety studied, seed tested soon after boll opening did not germinate fully. Before reaching its complete viability, cotton seed needs several days of rest, depending on date of maturity, variety, and, no doubt, other factors. For bolls opening early in the season, about 25 days are sufficient to enable the seed to germinate satisfactorily (about the same interval is given by Hsi and Reeder (15). Bolls opening later, however, require over 40 days, and the last to mature may need 5 months or even more. Differences between varieties were not clear cut, but were unmistakable for the American–Egyptian hybrid 53Δ. Light or normal irrigation did not appreciably affect the rate of germination.

A more pronounced effect of dormancy was observed in the data on the time of germination (table 2). Seeds tested soon after boll dehiscence require a considerably longer time for germination than those from successively later dates. Differences (C—A), (B—A) or (C—B), expressed as percentages of the sprouting time needed by the seed with the earlier boll dehiscence (figure 2a), show beyond doubt that in the extreme case (C—A), an almost 100% difference decreases gradually with the time of storage. Even 5 months later, however, seed C germinated later than A by about 25%. The same applies to differences (B—A) and (C—B), but these differences are necessarily smaller since the difference in time of boll dehiscence between B and A or C and B, is smaller than C and A. On the other hand, the effect of variety was quite important, particularly during the first 2 months after picking (figure

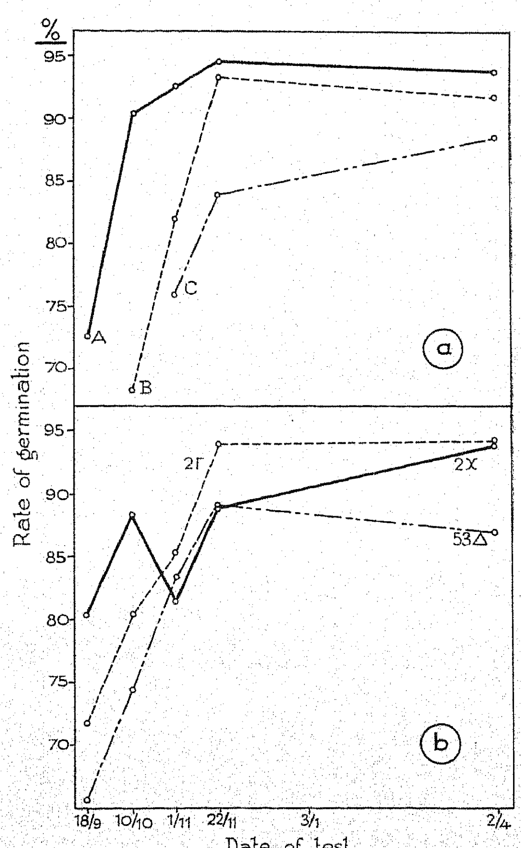

FIG. 1.—Rate of germination, as affected by the date of boll dehiscence (a) or variety (b), in successive tests.

Table 2.—Mean time of sprouting (in hours) for different cotton varieties and dates of boll-opening, in successive germination tests.

Seed groups		Date of test					
		1948				1949	
		Sept. 18	Oct. 10	Nov. 1	Nov. 22	Jan. 3	Apr. 2
2χ	A	86.4	60.8	53.9	84.0	42.5	55.2
	B	——	99.6	80.0	116.0	56.2	58.7
	C	——	——	112.0	143.5	68.5	67.0
	Mean	86.4	80.2	81.9	114.5	55.7	60.3
2Γ	A	92.2	59.9	54.3	74.7	45.0	55.2
	B	——	123.6	85.0	108.0	56.9	63.5
	C	——	——	121.2	138.0	74.3	68.1
	Mean	92.2	91.7	86.8	106.9	58.7	62.3
53Δ	A	87.1	62.5	62.1	81.2	47.0	57.4
	B	——	86.4	79.1	101.8	57.5	63.4
	C	——	——	105.6	131.8	58.7	68.0
	Mean	87.1	74.4	82.2	104.9	54.4	62.9
	A	88.6	61.1	56.7	80.0	44.8	55.9
	B	——	103.2	81.4	108.6	56.9	61.9
	C	——	——	112.8	137.8	67.2	67.7
General mean		88.6	82.2	83.6	108.8	56.3	61.8
L.S.D.:							
Varieties		n.s.	5.6	4.1	5.7	3.0	n.s.
A, B, C,		——	3.9	4.2	5.1	3.1	2.3
Interaction		——	6.8	7.3	n.s.	5.4	n.s.

2b), and the interaction variety × date of boll opening also proved to be significant.

The evidence discussed in the preceding paragraphs points definitely to the conclusion that cotton seed goes through the resting period of dormancy. Judged by the rate of germination, it may last from 25 to as many as 150 days (according to circumstances), whereas according to its effect on the earliness of germination, its duration extends to several months (in the American-Egyptian variety 53Δ dormancy effects are less pronounced than in the other two varieties). Accordingly, soon after harvest, the viability of cotton seed cannot safely or accurately be assessed by the ordinary test. Special methods are needed in this respect, and the one suggested by Lakon (16, 17) seems very promising.

Whatever the effect of dormancy on the rate or earliness of germination, the respective seeds proved equivalent for sowing purposes. Four of the most important agronomic characters of cotton, i.e. yield, lint length, earliness in maturity, and ginning out-turn, remained unaffected. The common practice widespread among farmers, namely, to use seed from only first pickings, does not seem warranted in the light of this study.

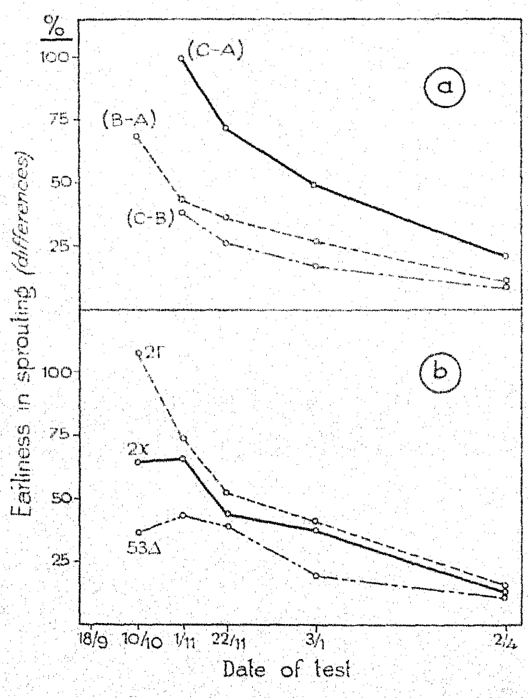

FIG. 2.—Earliness in sprouting (differences C-A, B-A, or C-B, as percentages of the time needed by the seed with the earlier date of dehiscence), according to date of dehiscence (a) or variety (b), in successive tests.

SUMMARY AND CONCLUSIONS

1. Experiments were carried out in Greece, at the Cotton Research Institute, for studying the effect of dormancy in cotton seeds.

2. As judged by the rate of germination, dormancy effects may last from 25 to as many as 150 days, depending on the date of boll dehiscence, variety, and possibly other factors. No differences were found between light and normal irrigation.

3. In earliness of germination, dormancy had a very pronounced effect lasting for several months. As in the rate of germination, this effect also varied under different conditions.

4. Differences in dormancy may be found between varieties, including an American-Egyptian hybrid.

5. Seeds differing in dormancy, when sown later in the

field, did not affect yield, lint length, earliness in maturity or ginning out-turn.

6. The use of seed from only first pickings, generally advocated by the farmers, would not be justified by the results obtained in this study.

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Tap Root Survival of Ladino Clover[1]

Fred E. Westbrooks and Milo B. Tesar[2]

LADINO clover, a variety of the large type of white clover (*Trifolium repens* L.), has become well established as a pasture legume in the humid Northeastern United States and Great Lakes area in the last two decades (4). Investigators are generally agreed that this legume is most productive the year after seeding and is usually less productive in the second year. Its productivity during the third and subsequent years varies considerably, being good in some years and poor in others.

Fertilizer use, choice of associated species, and proper grazing management to permit adequate carbohydrate storage and natural reseeding are among the most important practices recommended to prolong the productivity of this legume over a period of several years (1, 2, 3, 4, 5, 7).

Thinning of the stand is immediately evident when the tap roots of non-vegetatively propagated legumes like alfalfa (*Medicago sativa*) and red clover (*Trifolium pratense*) die. However, when the tap root of a stoloniferous legume like Ladino clover dies, the thinning indicative of a poorer stand is not immediately evident. The surviving stolons continue to grow and produce leaves after the tap root is dead. Such stolons have relatively short, fibrous roots incapable of deep soil penetration so necessary for high forage production in dry seasons.

Investigators cited above recognize that cold temperature injury to stolons is important in reducing the vigor of the Ladino clover plant. None of these studies, however, showed when the tap root died in the life history of this legume. It has been reported[3] that there were no living tap roots of the original plants in a field of Ladino clover in September after the second pasture year. Jeffers[4] found

[1] Contribution from the Department of Farm Crops, Michigan Agr. Exp. Sta., East Lansing, Mich. Journal article 1739. The results are part of the material submitted by the senior author in partial fulfillment of the requirements for the Ph.D. degree of Michigan State College. Received March 7, 1955.

[2] Assistant Professor in Agronomy, Tennessee A. and I. State University, Nashville, formerly graduate student in the Department of Farm Crops, and Associate Professor of Farm Crops, Michigan State University, respectively.

[3] Tesar, Milo B. Panel discussion on pasture irrigation. Abstracts, 1950 annual meeting, American Society of Agronomy, 1950.

[4] Jeffers, Robert L. The effect of soil fertility and height and frequency of defoliation on yield and survival of Ladino clover. Unpub. Ph.D. thesis. University of Wisconsin Library, Madison, Wis. 1951.

no living crowns or tap roots of the original plants in a 3-year-old stand of Ladino clover.

More information on the length of life of the tap root of this clover under various cutting and fertilizer treatments would help in developing methods for maintaining it under pasture conditions. The studies reported here are concerned with *(1)* the time of death of the tap roots, *(2)* effects of fertilizer and cutting treatments on the time of root death, and *(3)* possible causes of root death.

MATERIALS AND METHODS

Seed of a new variety of the large type of white clover (Pilgrim, F. C. 23608) similar in plant form and size to the variety Ladino was planted in flats in July of 1951, 1952, and 1953. Seedlings were transplanted to the field each year in early August on the Michigan State University Farms near East Lansing. The plants were set in a checkerboard pattern with 6 inches between plants. Each plant was marked with a white spike driven down to the ground level.

The soil was a Conover silt loam of pH 6.7, a tiled soil generally high in fertility and well adapted to corn, small grains, and legumes. Two fertility treatments—400 pounds of 0–20–20 and 0–20–0 fertilizer drilled into the soil prior to transplanting—were used in each of four replications of a randomized block design. The plots, 10 by 15 feet in size (10 by 10 in 1953), were located over tile lines to facilitate good drainage and minimize heaving. Each replication had 1,200 plants in 1951 and 1952, and 600 plants in 1953. All plots were clipped 4 times to a height of 3½ inches each season to simulate a rotational system of grazing.

The numbers of dead tap roots and roots showing some deterioration in 100 previously-marked plants were determined monthly by removal of the roots from the soil. Determinations began in July (12 months after seed was planted) on the plants established in 1951, 1952, and 1953 and continued until all plants were dead. Disease organisms were isolated in June 1953 from 100 tap roots of plants established in July 1952.

Living roots and the basal 6 inches of live stolons of plants established in 1952 were obtained for carbohydrate analysis. Starting in mid-September 1952 and continuing at monthly intervals through June 1954, plant samples obtained were washed, dried at 65°C. for 2 weeks, ground to pass through a 60-mash sieve, and stored in stoppered bottles for analysis. The amounts of total available carbohydrates were determined according to the method of Weinman (8). Duplicate 150-mg. samples were used. Percentages of total available carbohydrates are expressed on the dry weight basis.

Fifty roots and crowns from each fertility treatment were removed monthly from October 1953 through April 1954 from plots established in July 1952 and 1953. After clipping the stolons from the crown and cutting the tap roots back to a length of 2 inches, 5 plants were planted in each of ten 10-inch pots. The percentages of dead roots and the amount of lateral root and leaf growth produced in a 3-month period in the greenhouse were recorded for each monthly planting.

Because of the similarity in form between the common variety Ladino and the new variety Pilgrim, the variety name Ladino will be used to identify the large type of white clover in this paper even though the Pilgrim variety was used in this study.

RESULTS

Death of Tap Roots

No difference was noted between the survival of tap roots of plants grown on soil treated with 0–20–0 or 0–20–20 fertilizer. For this reason, the data for the two analyses of fertilizer have been averaged to simplify presentation.

Dead tap roots of plants established in July 1951 were first noted in December 1952, 17 months later (table 1). Dead roots of plants established in July 1952 and 1953 were first noted in July 1953 and 1954, respectively, 12 months after establishment. All of the tap roots of plants established in 2 different years were dead in July of the second production year.

The maximum mortality rate of tap roots during any 1-month period occurred between April and May 1954 in plants established in July 1952. The percentage of dead roots rose from 58 to 80 during that period. Roots of plants established in 1951 died most rapidly from May (53% dead) to June (72% dead) in 1953, when they were a month older than those established in 1952. The death rate between April and May was nearly as high, however, the percentages of dead roots being 35 and 50 for the 2 months, respectively.

Root Deterioration

Tap root deterioration was first manifested as blackening of the exterior root tissue. This was followed by pitting of these outer tissues, further darkening, loss of lateral roots and, finally, death and complete root deterioration.

Deterioration of roots was first observed in October 1952 on plants started in 1951, 15 months after plants were established in the field (table 1). The percentage of roots

Table 1.—Percentages of dead Ladino clover tap roots and percentages showing deterioration beginning in May, the first year after establishment in July 1951, 1952, and 1953.

Month	Age of plants, months	Year established					
		1951		1952		1953	
		Dead	Deteri-orated	Dead	Deteri-orated	Dead	Deteri-orated
May	10	0	0	0	0	0	0
June	11	0	0	0	40	0	42
July	12	0	0	0	90	0	87
Aug.	13	0	0	10	100	12	100
Sept.	14	0	0	25	—	—	—
Oct.	15	0	6	30	—	—	—
Nov.	16	0	24	33	—	—	—
Dec.	17	9	65	36	—	—	—
Jan.	18	16	72	40	—	—	—
Feb.	19	20	90	48	—	—	—
Mar.	20	28	100	52	—	—	—
Apr.	21	35	—	58	—	—	—
May	22	53	—	80	—	—	—
June	23	72	—	93	—	—	—
July	24	100	—	100	—	—	—

showing deterioration increased from 6 in October to 100 in March, 1953. In December, 2 months after the initial deterioration of the roots was noted, 9% of the roots sampled were dead (table 1). In March when all of the roots were showing external tissue deterioration and many were badly discolored, 28% of the 100 roots sampled were dead. Four months later, all original tap roots were dead.

Deterioration was first observed in June 1953 on the roots of plants established in July 1952. At this time 40% of the 100 roots sampled showed symptoms of deterioration. The percentage of roots affected increased rapidly. In August, 100% of the roots showed deterioration, some very noticeably and 10% were dead. The rate of root deterioration of plants established in 1953 was very similar to that of plants established in 1952. Photographs in figure 1 show the progressive stages of deterioration of roots and plants established in 1952.

Even though the plants established in 1951 showed root deterioration later (October) than plants established in 1952 and 1953 (June), there is a striking similarity in root death in the 3 years. Initial root death was noted 2 months after deterioration was first observed in the 3 stands established in the 3 different years.

Disease Organisms

A total of 100 fungus isolations was made on tap roots of plants established in 1952 when symptoms of root deterioration were detected in June, 1953. Of the fungi isolated, *Fusarium oxysporum, F. solani,* and *Rhizoctonia* species constituted 48, 6, and 19%, respectively, of the total isolates (table 2). The other fungi isolated were either weakly- or non-pathogenic. The presence of the three pathogenic fungi, however, does not imply that the deterioration noted was a diseased condition caused by these organisms. Deterioration may have occurred first followed by invasion of these fungi. There is a striking similarity in the appearance of these roots and the diseased roots of red clover shown by Kilpatrick, *et al.* (6).

Table 2.—Percentage distribution of fungus organisms in 100 isolations made in June 1953* from roots of Ladino clover plants established in July 1952.

Organism	Percentage of total isolates
Fusarium oxysporum	48
F. roseum	17
F. solani	6
Rhizoctonia spp.	19
Mucor spp.	6
Rhizopus sp.	1
Basisporium sp.	1
Other	2
Total	100

* Made by E. W. Hansen, Pathologist, Division of Forage Crops and Diseases, Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture, University of Wisconsin, Madison, Wisconsin.

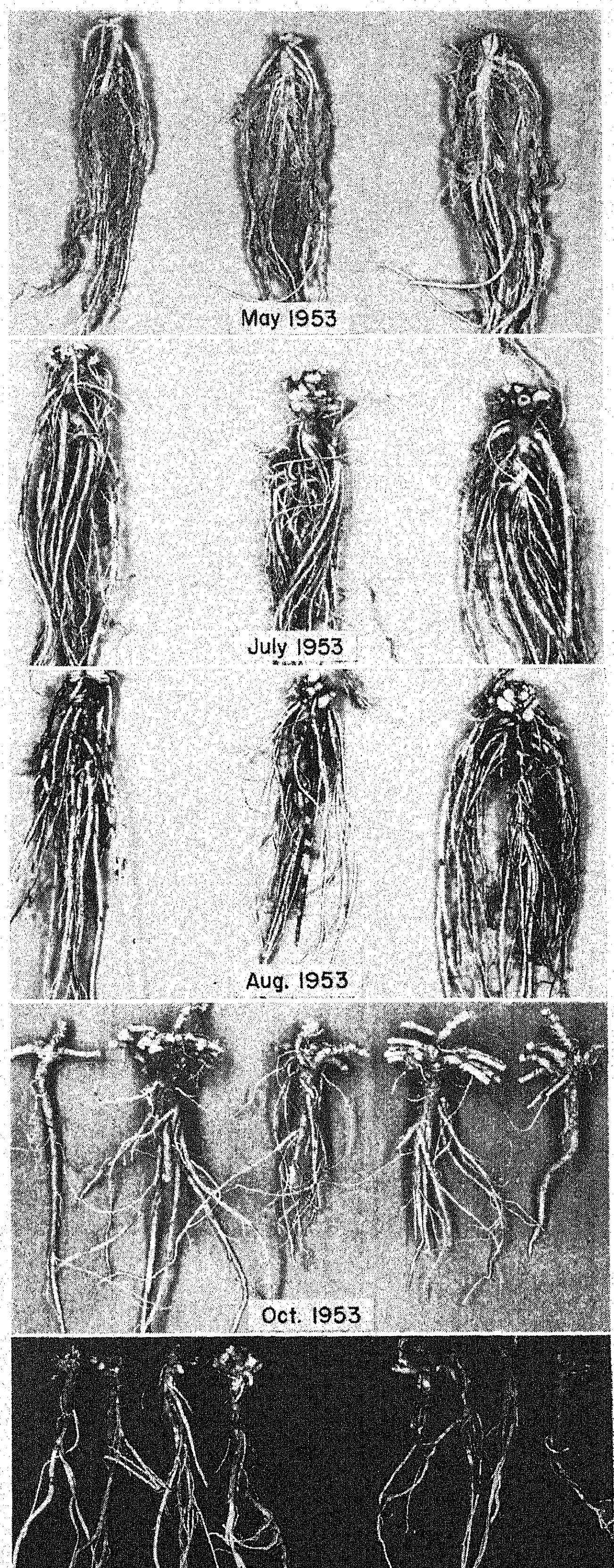

FIG. 1.—Progressive stages of root deterioration showing healthy roots in May 1953 of the first production year and increasing deterioration and loss of lateral roots until May 1954 of the second production year, one month before all tap roots were dead.

FIG. 2.—Leaf production produced after 3 months' growth in the greenhouse by plants going through their (1) first and (2) second winter following establishment.

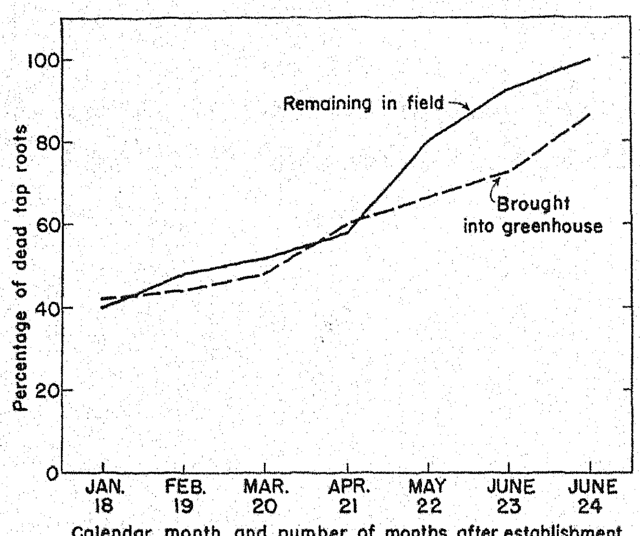

FIG. 3.—Percentages of dead tap roots removed from the field in months indicated compared to roots transplanted from the field to the greenhouse three months earlier and harvested in the month indicated. Plants established in July 1952.

Death of Tap Roots in Greenhouse

In October 1953 and monthly thereafter until April 1954, 50 tap roots and crowns were obtained from each of the 2 fertility treatments from plants established in July 1952 and 1953. The plants were transplanted into pots in the greenhouse. Forty-two percent of the roots of plants started in 1952 were dead 3 months after transplanting in October 1953. The percentage of dead tap roots of plants transplanted monthly from October to April increased each month until 87% of the plants transplanted to the greenhouse from the field in April were dead 3 months later in July (table 3). In striking contrast, none of the tap roots of the plants established in 1953 (going through their first winter) died when removed from the field to the greenhouse during the same period.

Roots from plants established in 1952 and transplanted monthly from January through April 1954 showed, in the greenhouse, a mortality rate similar to those remaining in the field under winter conditions for a similar 3-month period (figure 3 and tables 1 and 3). This would indicate that some factor other than winter injury occurring in the field was the important cause of death. However, roots taken from the field in March and April and allowed to grow 3 months in the greenhouse showed a lower mortality than those allowed to stay in the field during this 3-month period. Thirteen percent of the roots sampled from the field in April and grown for 3 months in the greenhouse were alive in July; all roots remaining in the field were dead in July.

Table 3.—Survival of 100 tap roots brought into the greenhouse at monthly intervals from plants established in July 1952. Percentage readings were made three months after roots were taken from field.

Transplanted from field	Time of determination		Dead roots %
	Month	Age, months	
Oct. 1953	Jan. 1954	18	42
Nov.	Feb.	19	44
Dec.	Mar.	20	48
Jan. 1954	Apr.	21	60
Feb.*	May	22	—
Mar.	June	23	73
Apr.	July	24	87

* No plants transplanted.

Table 4.—Percentages of total available carbohydrates in roots and stolons of Ladino clover plants established in July 1952.

Month	Age of plants, months	Roots	Stolons
Sept., 1952	2	26.11	21.68
Oct.	3	29.15	25.87
Nov.	4	34.33	27.08
Dec.	5	31.77	24.34
Jan., 1953	6	24.16	19.16
Febr.	7	22.66	13.76
Mar.	8	20.48	12.65
Apr.	9	9.62	11.38
May	10	11.25	12.32
June	11	11.38	12.65
July	12	13.76	17.70
Aug.	13	15.19	19.60
Sept.	14	17.25	27.77
Oct.	15	21.08	29.15
Nov.	16	24.76	25.87
Dec.	17	23.68	24.76
Jan. 1954	18	18.93	20.57
Febr.	19	16.62	17.00
Mar.	20	13.32	16.02
Apr.	21	9.25	14.00
May	22	7.57	8.75
June	23	8.76	12.02

Leaf Production in Greenhouse

The amount of leaves produced by plants in the greenhouse was determined after 3 months' growth. Plants in their first winter produced at least twice as much top growth and had much more vigorous leaves than those in their second winter (figure 3). The amount of top growth produced by plants in their first winter could not be accurately

compared to those 1 year older because of the large number of plants which died in the second winter.

Total Available Carbohydrates

Roots and stolons of plants established in 1952 had 26.11 and 21.68% total available carbohydrates, respectively, in mid-September, 2 months after establishment (table 4). The percentages rose gradually from September to November in both roots and stolons, the levels being 34.33 and 27.08, respectively.

Percentages of total available carbohydrates decreased gradually from November to March. During this period, the percentage in roots dropped from 34.33 to 20.48 and in stolons from 27.08 to 12.65. The percentage in roots decreased rapidly from 20.48 in March to 9.25 in April. From April through the summer months of the first production year, the percentage of carbohydrates increased gradually until November. At this time the roots had a maximum percentage of 24.76 (about 10% lower, however, than roots sampled 1 year earlier). Stolons reached their maximum percentage (29.15) in October, 1 month earlier than the roots. This level of carbohydrates was only slightly lower than that of stolons sampled 1 year earlier.

Actually the percentage of total available carbohydrates in stolons was very similar in comparable months of the first and second year of the sampling period beginning in September. In striking contrast, the percentage of total available carbohydrates of roots in their second winter was much lower than that of roots in their first winter.

DISCUSSION

Data presented show that initial death of some of the roots of Ladino clover established in July 1952 and 1953 occurred in August of the first production year. Root death of plants established in July 1951 was first noticed in December following the first production year. The tap roots of all three plantings were all dead in July of the second production year, 2 years after establishment. The difference in the later root death of plants established in 1951 is difficult to explain. There is undeniably a close relationship between initial blackening and death of the tap roots. In each of the 3 plantings, initial death of some roots occurred 2 months after first symptoms of blackening were observed. If disease organisms were responsible for this observed blackening of the outer root tissue, the initial infection may have occurred earlier on plants established in 1952 and 1953 than on those established in 1951.

Data show that the percentages of total available carbohydrates in the roots were at a low level during the second winter and decreased progressively until spring. The percentages of living roots, likewise, continued to decrease during this period up to July when all were dead. It cannot be assumed that this death was due primarily to the decreased percentage of total available carbohydrates in the roots. The low percentages of carbohydrates may have been the result, rather than the cause, of root death.

It has been shown that 13 percent of the roots sampled from the field in April and grown for 3 months in the greenhouse were alive in July of the second production year while all roots remaining in the field were dead in July. This suggests that *(1)* initiation of new growth at the expense of stored carbohydrates reserves under field conditions in the spring, and/or *(2)* fluctuating spring temperatures might accelerate the rate of mortality of roots under field conditions. It suggests that "winter injury" of roots might take place in the spring as well as in winter.

It is likely that some or all of the disease organisms present on the roots as early as June of the first production year were the cause of root death. Injury to the roots from disease may have resulted in a lesser ability of the plant to store carbohydrates in the root prior to the second winter. The resulting lower level of total available carbohydrates in the roots during the second winter may have accentuated root death.

PART II—MATERIALS AND METHODS

Studies were initated in the spring of 1953 on a Ladino clover field seeded in August 1952 on the Michigan State University Farm to determine the effects of cutting treatments, fertility levels, analyses of fertilizer, and dates of application of fertilizers on the survival of tap roots and the production of forage.

Ladino clover (F. C. 23,608, variety Pilgrim) was band-seeded at the rate of 2 pounds per acre 1 inch above 0–20–20 fertilizer applied at the rate of 400 pounds per acre. A regular grain drill adapted into a band seeder with 7-inch spacings between disks was used. The soil, a Hillsdale sandy loam, has medium inherent fertility with good drainage.

A split-split-plot design, in which all cutting treatments, fertilizers, and dates of application of fertilizers occurred in each of the four replicates was used. Individual plots were 7 by 12.5 feet. In addition to the fertilizer applied at seeding, 200 and 600 pounds of either 0–20–20 or 0–20–0 fertilizer were top dressed on different plots on May 23, June 23, and Sept. 15, 1953, during the first production year. Similar amounts of the same fertilizers were applied as split applications (½ of the total amount on each date) on other plots on May 23, June 23, Aug. 20, and Sept. 15. Another group of plots received no additional fertilizer as a topdressing.

In 1953, plots were cut either 4 times to a height of 3½ inches or 6 times to a height of 1 inch to simulate heavy and light grazing, respectively.

On May 25, 1953, the numbers of living plants in a 2-foot single drill length of a row of clover seeded in 1952 were counted in each of 32 plots to obtain an average or "base count" of living roots in the field on that data. This length of row represented an area of 1.17 square feet. On Sept. 25, 1953, the living tap roots of plants in each plot in the experiment were counted in a 2-foot length of row, marked on the 2 ends with white spikes driven down to the ground level. A similar count of Ladino clover tap roots was made in April and June 1954 by digging up roots of plants in a similar 2-foot length of row adjacent to the row marked in September 1953. The number of living or dead tap roots in the original length of row (counted September 1953) was determined by digging up roots of plants in July 1954. All results are reported on the basis of the average number of tap roots for a 2-foot length of row.

To measure the effects of various management and fertilizer treatments imposed in 1953 on yields in 1954, the forage was harvested to a height of 1 inch on May 29 and July 10, 1954. The area harvested was 2.88 feet wide through the center of a plot 12.5 feet long. Yields for the two harvests are reported in tons per acre of oven-dry, weed-free hay.

RESULTS

Effects of Cutting Treatments

In April and June 1954, the number of tap roots still alive was significantly lower when plants were previously cut 6 times to a height of 1 inch than when cut 4 times to a height of 3½ inches in 1953 (table 5). None of the roots of clover given the more severe cutting treatment in 1953 was alive in June 1954. Six percent were alive on plots cut less severely but these were all dead in July. The slightly higher mortality rate of roots on the clover cut closely and frequently in 1953 was undoubtedly associated with the higher amount of heaving noted on these plots than on plots cut higher and less frequently in 1953.

Table 5.—Number of living tap roots in 1.17 square feet and the percentage survival of tap roots of Ladino clover seeded in 1952 and given different cutting treatments in 1953. Average for all fertility treatments.

Cutting treatment 1953	May 1953*	Sept. 1953		Apr. 1954		June 1954		July 1954	
	Living tap roots and percentage survival								
	Number	Number	%	Number	%	Number	%	Number	%
6 times to 1 inch	23.9	13.6	56	1.3	5	0.0	0	0.0	0
4 times to 3½ inches	23.9	15.0	63	3.7	15	1.6	6	0.0	0

L.S.D. for numbers of roots:	5%	1%
Vertical	1.6	2.4
Horizontal	2.1	2.9

* Count made in May was considered 100%.

Rate and Analysis of Fertilizer

Top dressing with 600 pounds of 0–20–20 fertilizer during the first production year (1953) resulted in fewer dead roots in September 1953 than when similar amounts of 0–20–0 or no fertilizer was applied (table 6). However, none of the fertilizer treatments had any significant effect in prolonging the life of the tap roots beyond June 1954 of the second production year. All roots sampled were dead in July regardless of previous treatment.

Time of Fertilizer Application

Plots topdressed with fertilizer in June and September 1953 had a significantly higher number of living tap roots in September 1953 than those receiving no fertilizer (table 7). In April, June, and July 1954, no significant difference was noted among any of the previous treatments applied in 1953. While certain dates of application of fertilizers increased the number of living tap roots present at the end of the first production year, no treatment caused the tap roots to survive longer than June of the second production year.

Forage Production

Ladino clover subjected to less severe cutting in 1953 (4 times to a height of 3½ inches) was significantly higher in yield in 1954 than clover cut 6 times to a height of 1 inch in 1953, yields being respectively, 1.61 and 1.29 tons of hay per acre (table 8).

In 3 out of 4 cases, the yields obtained as a result of topdressing with fertilizer were greater (1% level) than yields obtained when no fertilizer was applied. The greatest difference occurred between the yield of clover which was not topdressed (1.30 tons) and clover topdressed with 600 pounds of 0–20–20 per acre (1.62 tons). Application of 600 pounds of 0–20–0, however, did not produce a yield higher than those obtained when 200 pounds of 0–20–0 or 0–20–20 were applied. On this sandy loam soil, addition of a large amount of potassium was apparently necessary for the highest yield. There were no significant differences among 1954 yields of Ladino clover topdressed in May, June, September or when given a split application of fertilizer on four dates during the growing season in 1953.

DISCUSSION

Results presented here are in close agreement to those presented in Part I in that all tap roots sampled were dead in July of the second production year. Whereas an average of 37% of the roots were dead in this experiment in September following the first production year on plots cut 4 times to a height of 3½ inches, 25% were dead when given the same cutting treatment in the first experiment reported in Part I.

Table 6.—Number of living tap roots in 1.17 square feet and the percentage survival of tap roots of Ladino clover seeded in 1952 and given different fertilizer treatments in 1953. Average for two cutting treatments.

Rates and fertilizers applied 1953	Sampling dates								
	May 1953*	Sept. 1953		Apr. 1954		June 1954		July 1954	
	Living tap roots and percentage survival								
	Number	Number	%	Number	%	Number	%	Number	%
None	23.9	12.8	53	2.1	9	0.9	4	0.0	0
200 lbs. 0–20–0	23.9	14.1	59	2.5	10	0.7	3	0.0	0
600 lbs. 0–20–0	23.9	13.6	57	2.6	11	0.8	3	0.0	0
200 lbs. 0–20–20	23.9	15.2	64	2.9	12	0.8	3	0.0	0
600 lbs. 0–20–20	23.9	15.7	66	2.4	10	0.6	2	0.0	0

L.S.D. for numbers of roots:	5%	1%
Vertical	1.6	2.2
Horizontal	1.8	2.4

* Count made in May 1953 was considered 100%.

Table 7.—Number of living tap roots in 1.17 square feet and the percentage of tap roots of Ladino clover seeded in 1952 and fertilized at different times in 1953. Average for cutting treatments and two levels of 0–20–0 and 0–20–20 fertilizer.

Dates of fertilizer application 1953	Sampling dates								
	May 1953*	Sept. 1953		Apr. 1954		June 1954		July 1954	
	Living tap roots and percentage survival								
	Number	Number	%	Number	%	Number	%	Number	%
None	23.9	12.8	53	2.1	9	0.9	4	0.0	0
May 23	23.9	14.2	59	2.6	11	0.4	2	0.0	0
June 23	23.9	15.0	63	3.0	13	1.0	4	0.0	0
Sept. 15	23.9	14.6	61	1.7	7	0.7	3	0.0	0
Split applications†	23.9	14.2	59	2.6	11	1.0	4	0.0	0

L.S.D. for numbers of roots:	5%	1%
Vertical	1.8	2.4
Horizontal	2.0	2.8

* Count made in May was considered 100%.
† Split application plots received ¼ of the respective fertilizer on May 23, June 23, Aug. 20 and Sept. 15.

The continued greater root survival on the heavier soil in Experiment I was evidenced the following April (1954) at which time 58% of the roots were dead whereas 85% were dead on the lighter soil. This 85% figure represented an average for the non-fertilized and fertilized clover. Differences were so small that extra tables to show differences were not warranted. The heavier soil type and the 6-inch spacing between plants in the experiment in Part I may explain why those roots showed a lower rate of mortality in September and April following the first production year.

It was expected that this experiment (Part II) would provide information which would prolong the life of the tap root of Ladino clover. Reducing the severity of cutting treatments and topdressing with fertilizer containing phosphorous and potassium during the first production year reduced the rate of root mortality prior to the second production year. No fertilizer or cutting treatment, however, was effective in prolonging the life of the tap roots beyond June of the second production year.

This is further corroborated by a survey conducted by the senior author[5] in farmers' fields in eight counties in Michigan. In these surveys, none of the 25 samples each 50 square inches in size made in each field showed any living tap roots in July of the second production year.

Since neither management nor fertilizer treatment materially increased the length of life of tap roots in the experiments reported in Parts I and II of this study, it appears that the continued productive life of this legume in a forage stand would have to depend on rooted stolons or new plants established from seedlings. Rooted stolons are, at best, drouth susceptible and subject to severe winter injury as shown by Jeffers (see footnote 4). It would appear that the productivity of a stand of Ladino clover after the middle of the second production year would be low unless new plants were established from natural reseeding. This establishment of seedlings is indicated by the general survey reported above. Three to sixty-one percent of the seedlings counted during the second production year became established plants the next year. Even though the plants were vigorous and were contributing to the productivity of Ladino clover in the fields, the exact amount produced by these plants could not be determined accurately.

[5] Westbrooks, Fred E. Life history studies of Ladino clover in Michigan. Unpub. Ph.D. Thesis. Michigan State University Library, East Lansing, Mich., 1954.

Table 8.—Effect of cutting treatments and time of application of fertilizer treatments in 1953 on the tons of hay produced in 1954 by Ladino clover seeded in 1952.

Cutting treatment, 1953	Fertilizer treatment per acre					
	None	0–20–0		0–20–20		Average
		200 lbs.	600 lbs.	200 lbs.	600 lbs.	
6 times to 1 inch	1.12	1.21	1.20	1.22	1.43	1.28
4 times to 3½ inches	1.48	1.56	1.58	1.62	1.82	1.61
Average	1.30	1.38	1.39	1.42	1.62	1.45

L.S.D.	5%	1%
Over all averages of cutting	.28	.51
Between same fertilizer treatment between cuttings	.29	.51
Over all averages of fertilizers	.07	.09

Since most of the tap roots of Ladino clover in this study were dead in May of the second production year and the remainder were dead by July, the life history of this plant can be considered very similar to that of red or alsike clover (*Trifolium hybridum*) under field conditions. The continued life of the stolons under favorable conditions and/or establishment of new plants from natural reseeding, however, often make this legume perform like a perennial.

SUMMARY

Ladino clover was established in the field by *(1)* space-planting seedlings in a 6-inch checkerboard pattern on a silt loam soil in the summers of 1951, 1952, and 1953 and by *(2)* band-seeding directly on a sandy loam soil in the summer of 1952. The space-planted clover was fertilized with 400 pounds per acre of 0–20–20 or 0–20–0 fertilizer

when established. The clover which was band seeded was fertilized with 400 pounds per acre of 0–20–20 fertilizer when established and then *(1)* not fertilized or *(2)* topdressed with 200 or 600 pounds of 0–20–0 or 0–20–20 fertilizer applied at different times during the first production year. This clover was cut 6 times to a height of 1 inch, or 4 times to a height of 3½ inches during the first production year.

Some tap roots were dead in the latter part of the first production year in three of the four trials. In the fourth trial, dead roots were not observed until in December following the first production year. In all cases, however, the percentage of dead roots increased steadily as the plants increased in age. In July of the second production year, all roots in sampled areas were dead on all plots.

Reducing the severity of cutting treatments and topdressing with fertilizer containing both phosphorus and potassium during the first production year effected a slowing down in root death. Neither treatment, however, prolonged the life of the tap roots beyond June of the second production year. Although fertilizer application did not reduce root mortality, it did result in increased forage production during the second production year.

Discoloration and deterioration of tap roots began as early as June of the first production year, two months before initial root death occurred. At this time, *Fusarium oxysporum, F. solani,* and *Rhizoctonia* species constituted 48, 66, and 19% respectively, of the fungi isolated. The presence of these three fungi, however, was not necessarily the cause of root deterioration and eventual death.

Percentages of total available carbohydrates in stolons were fairly similar on comparable sampling dates during the first and second year of the sampling period which began in September and continued until roots were dead. The percentages in roots of plants going through their second winter, however, were much lower than in those going through their first winter.

Roots of plants taken into the greenhouse monthly from October through January of the second fall and winter had as many dead tap roots 3 months later as roots allowed to remain in the field during this same period. However, 13% of the roots removed from the field in April were still alive in the greenhouse in July while all roots remaining in the field were dead. This suggests that the greatest amount of root death occurred in the spring rather than during late fall or winter.

A field survey of farmers' fields in eight counties in Michigan showed that the tap roots of Ladino clover were dead in July of the second production year regardless of management and fertilizer practices. This corroborated findings made under closely-controlled conditions in this study. Three to sixty-one percent of the seedlings counted in the different fields in the second production year became established plants the following year, indicating scattered seed was helpful in maintaining the stands of Ladino clover under field conditions in Michigan.

The exact cause of death of tap roots was not determined. Disease may have caused the deterioration and death of the roots but a pathological study is necessary to determine the importance of disease in root death. The lowered percentages of total available carbohydrates in roots during the second winter may have contributed to the final death of the roots.

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The Effect of Low Temperatures on Available Soil Moisture During Winters on the Canadian Prairies[1]

J. Wilner[2]

WINTER killing of plants resulting from desiccation of tissues has been frequently distinguished from killing resulting from low temperatures (6, 7, 8, 10). Winter desiccation has been recognized by the same workers to be due to the combined effect of soil or physiological drought, as well as to atmospheric drought. There is general agreement among these authors that physiological winter drought is a condition under which the plant is unable to absorb water from frozen soil, when there is an abundance therein, and when the aerial parts are in need of water as a result of the high evaporating power of the air. According to Meyer and Anderson (8) water in frozen soils is unavailable and none of it can be absorbed by roots to replenish the moisture lost by transpiration or evaporation.

It is also generally agreed[3] (7, 10) that most of the feeding roots of trees are in the upper 12 to 18 inches of soil. Crossley[3] showed that on the prairies as many as 65 to 80% of roots of boxelder (*Acer negundo*, L.) and ash (*Fraxinus pennsylvanica lanceolata*, (Borkh. Sarg.) trees may be found in the upper 12 to 18 inches of soil. It is apparent that factors affecting the upper 12 to 18 inch layer of soil will exercise a predominant influence over the growth and development of woody plants. The object of this exploratory study was therefore to determine, if possible, the effect of winter temperatures on the available moisture in the specified upper layer of soil, *per se*, and on the aerial parts of woody plants grown on the Canadian prairies.

EXPERIMENTAL PROCEDURE

This study was carried on during the winter periods from Nov. 4, 1952 to April 27, 1953, and Nov. 3, 1953 to April 26, 1954. During these periods the available soil moisture was determined by the plaster of paris electrical resistance method of Bouyoucos (2,3,4) and other workers (1,5). The blocks were placed at depths of 6, 12, 18, and 24 inches in the root zone of boxelder trees. The trees had been growing since 1943, in fairly level clay loam textured soil, in belts spaced 4 by 4 ft., 8 by 8 ft., and 16 by 16 ft., as well as 4 by 4 ft. with a light mulch on some trees and a heavy mulch on others. The belts were 540 feet long. From each of these belts four replicated boxelder trees were selected at random. The same trees with undisturbed moisture blocks were used during the 2 years' study.

RESULTS

Data in table 1 indicated no significant differences between soil moistures, when averaged for 19 periods, at the levels of 6, 12, and 18 inches. However, during both winters more moisture was found at the 24-inch level as compared with levels above 18 inches. The data also indicated a gradual significant decline in available soil moisture as the study progressed from Nov. 4 to Mar. 19 in 1953

Table 1.—Available soil moisture at four depths in the root areas of boxelder trees for specified dates during the dormant season of 1952–1953 and 1953–1954.

Dates	Depth in inches				Average
	0–6	6–12	12–18	18–24	
	Percent available soil moisture, average of 20 trees*				
Nov. 4, 1952	54	58	59	65	59
Nov. 10	52	56	59	64	58
Nov. 24	43	55	57	64	55
Dec. 1	7	39	55	63	41
Dec. 8	4	20	53	62	35
Dec. 15	2	12	50	61	31
Dec. 22	0	4	29	60	23
Dec. 29	0	1	13	56	17
Jan. 5, 1953	0	0	6	44	13
Jan. 12	0	0	2	31	8
Feb. 3	0	0	1	14	4
Mar. 4	0	0	1	11	3
Mar. 19	0	0	1	15	4
Apr. 2	50	21	11	34	29
Apr. 7	68	48	28	48	48
Apr. 14	66	53	38	58	54
Apr. 20	65	57	51	69	61
Apr. 23	68	58	54	71	63
Apr. 27	71	66	60	73	68
Mean	29	29	33	51	35
Nov. 3, 1953	55	30	16	26	32
Nov. 16	59	39	22	31	38
Nov. 23	46	41	27	35	37
Nov. 30	45	43	29	37	39
Dec. 7	31	42	31	39	36
Dec. 14	21	41	34	41	34
Dec. 21	10	31	34	43	29
Jan. 4, 1954	3	15	31	45	23
Jan. 11	3	7	23	45	19
Jan. 25	0	0	4	33	9
Feb. 8	0	1	6	30	9
Feb. 22	0	1	5	29	9
Mar. 15	0	1	6	39	11
Mar. 28	0	0	4	34	9
Apr. 7	0	0	2	21	6
Apr. 14	33	10	10	31	21
Apr. 19	48	21	13	34	29
Apr. 23	54	32	19	36	35
Apr. 26	62	51	35	46	48
Mean	25	21	18	35	25

L.S.D. at P = 0.05

Between means of dates within each season	17
Between means of depths within each season	7
Between individual determinations	33

* The averages of 20 trees were considered representative of the moisture at each depth of soil.

[1] Contribution of the Division of Horticulture, Experimental Farms Service, Canada Dept. of Agriculture. Received March 14, 1955.

[2] Agricultural Research Officer. Tree Physiology, Forest Nursery Station, Indian Head, Sask. Canada.

[3] Crossley, D. I. Rooting habits of maple (*Acer negundo* L.) and Ash (*Fraxinus pennsylvanica lanceolata* (Bork.) Sarg.) on the pedocals of Manitoba and Saskatchewan. Unpublished. M. Sc. Thesis, Univ. of Minnesota, 1940.

Table 2.—Recorded temperature and precipitation during periods of determining available soil moisture.

Winter 1952–1953				Winter 1953–1954			
Periods	Temperatures °F. Extreme Max.	Extreme Min.	Precipitation in inches	Periods	Temperatures °F. Extreme Max.	Extreme Min.	Precipitation in inches
Nov. 4	60	30	—	Nov. 3	43	23	—
Nov. 5–Nov. 10	42	20	—	Nov. 4–Nov. 16	61	23	.18
Nov. 11–Nov. 24	52	15	.38	Nov. 17–Nov. 23	42	10	.03
Nov. 25–Dec. 1	24	−5	—	Nov. 24–Nov. 30	36	14	.30
Dec. 2–Dec. 8	33	6	.07	Dec. 1–Dec. 7	41	6	.05
Dec. 9–Dec. 15	35	−1	.11	Dec. 8–Dec. 14	38	6	.05
Dec. 16–Dec. 22	32	−8	.05	Dec. 15–Dec. 21	36	−7	.01
Dec. 23–Dec. 29	26	−2	—	Dec. 22–Jan. 4	38	−20	.53
Dec. 30–Jan. 5	35	−3	.02	Jan. 5–Jan. 11	18	−22	.10
Jan. 6–Jan. 12	39	−18	.23	Jan. 12–Jan. 25	19	−40	.47
Jan. 13–Feb. 3	37	−32	.19	Jan. 26–Feb. 8	45	−33	.05
Feb. 4–Mar. 4	38	−17	.80	Feb. 9–Feb. 22	44	−9	.16
Mar. 5–Mar. 19	44	−22	.72	Feb. 23–Mar. 15	46	−18	.31
Mar. 20–Apr. 2	51	5	.99	Mar. 16–Mar. 28	37	2	.02
Apr. 3–Apr. 7	49	22	—	Mar. 29–Apr. 7	50	−12	.19
Apr. 8–Apr. 14	40	9	.17	Apr. 8–Apr. 14	64	22	—
Apr. 15–Apr. 20	39	6	.03	Apr. 15–Apr. 19	58	24	—
Apr. 21–Apr. 23	64	31	—	Apr. 20–Apr. 23	46	26	.44
Apr. 24–Apr. 27	59	28	—	Apr. 24–Apr. 26	50	28	.13
Range or Total	64 to 24	31 to −32	3.76	Range or Total	64 to 18	28 to −40	3.02

and Nov. 3 to Apr. 7, in 1954. Following these periods in two winters, significant increases in available soil moisture were recorded before the study terminated in 1953 and 1954. These data also revealed that during the periods, Dec. 29, 1952 to Mar. 19, 1953 and Jan. 25 to Apr. 7, 1954, the soil moisture for a depth of 12 inches was unavailable to plants. Beyond the 12 inch depth the soil moisture was at no time totally unavailable to plants during the test period. However, considering the wilting point of the clay loam soil, it is believed that little of the 1 to 6% moisture recorded at the 18-inch depth during the period of study would be available to plants.

The analysis of variance of data in table 1 showed that there were significant differences attributable to winters, depths and to different dates of study. Of the three interactions, between winters × periods, winters × depths, and periods × depths, the two which involved depths of soil were insignificant, while the interaction of winters × periods was significant at the 1% level.

Weather records (table 2) show that during the 80-day period of Dec. 29, 1952 to Mar. 19, 1953, and the 72-day period of Jan. 25 to Apr. 7, 1954, when a great deal of soil moisture was unavailable to plants, the air temperature ranged from 44°F. to —32°F. and from 50°F. to —33°F. respectively. During the 80-day period there were 17 days with maximum temperatures above freezing (32°F.) and on 3 of these 17 days, temperatures were above 41°F. During the 72-day period in 1954, there occurred 39 days with temperatures above freezing, and on 14 of these days temperatures were above 41°F. These temperatures could be considered high enough to affect certain metabolic activities and moisture losses from plants (8, 11, 12). It would appear that the combining effect of such atmospheric and soil conditions would be to augment the possibility of winter desiccation and permanent injury of woody plants on the Canadian prairies.

The data of table 2 also show that during the winter periods in which the soil moisture was in an unavailable form to over half of the feeding roots of boxelder trees, the extreme minimum air temperature was fairly consistently below freezing, ranging from 2°F. to —33°F. This would suggest that the unavailability of moisture in the upper 12 to 18 inches of soil to plants in winters may be due to low atmospheric freezing temperatures rather than to depletion of soil moisture. This conclusion is in agreement with other findings (1, 8).

DISCUSSION AND SUMMARY

Data from this exploratory study indicate mainly that the availability of soil moisture during the winters of 1952–1953 and 1953–1954 decreased with intensity and duration of low atmospheric temperatures. This soil condition extended to a depth of approximately 18 inches. This would suggest a possible retarding and obstructing effect on absorption and conduction of soil moisture in as much as 65 to 80% of the root system of trees[4] required to replenish the water lost through transpiration and evaporation.

Two years' data indicated that the frozen soil moisture to a depth of 12 to 18 inches was unavailable to plants for about 2½ winter months. During these periods there were numerous days with temperatures above 32°F. and sometimes above 41°F., which would be high enough to stimulate certain metabolic activities and to affect desiccation of plant tissues (8, 11, 12). Such commonly occurring combination of soil and air conditions in winter could be a contributing factor to winter desiccation and permanent injury of plants on the prairies. Further intensive study to explore this phenomenon of winter killing of plants, especially evergreen species, is being contemplated as the result of this investigation.

[4] Crossley, *ibid.*

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Stem-Break in Senescence in Oats[1]

J. E. Grafius, H. M. Brown, and R. L. Kiesling[2]

THE use of the combine and the accompanying tendency to let the oat crop stand in the field after maturity has resulted in a peculiar type of lodging called stem-break. Stem-break is an "old age" form of lodging occurring after the plant is dead ripe.

The use of a lodging resistance factor, cL_r, as a measure of lodging resistance in the green plant was developed in a previous paper[3] This paper on stem-break in senescence makes a natural sequence. Fortunately, resistance to this form of lodging is readily measured by letting the guard rows stand after harvest until the culms start to crinkle or break. Hence the problem is not so much one of measurement and prediction as one of determining the factors involved.

The purpose of this paper is to determine some of the factors involved in stem-break in senescence and to find out if varieties resistant to lodging as measured by the cL_r factor tend to resist stem-break.

MATERIALS AND METHODS

The percentage of broken culms (stem-break) was recorded for the guard rows of micro-yield plots in 2 oat nurseries, 11 days after harvest. There were 44 varieties in nursery A and 42 in nursery B, with 3 and 4 replications, respectively. Both nurseries were in the same field, in the vicinity of East Lansing, Mich. Except for three check varieties, each nursery was comprised of different varieties.

Lodging resistance factor readings were taken earlier in the season on the green plant at the early dough stage. The lodging resistance factor has been previously (2) described as $cL_r = \dfrac{F}{b}$, where F = the weight in grams of chain supported and b = the height to the base of the head in centimeters. The constant c is a factor which converts the height b into force. Five cL_r readings were taken per plot. Hereafter these readings will be referred to as lodging resistance readings.

Date of heading notes were taken according to standard procedure.

The *Leptosphaeria avenaria* G. F. Weber *(Septoria avenae* Frank) notes were taken on a scale of 1 to 5, with 5 being severe.

Correlation coefficients were calculated using variety means.

EXPERIMENTAL RESULTS

Three factors were observed to be associated with stem-break percentage. These were lodging resistance readings, maturity as measured by date of heading, and *Septoria* readings. The interrelationship between these variables is most readily established by means of simple correlation coefficients as shown in table 1.

In table 1 it may be seen that coefficients for maturity *vs.* stem-break and lodging resistance *vs.* stem-break are highly significant and of about the same magnitude. The relationship between stem-break and *Septoria* readings is significant in one case. It will also be noted that the coefficients for maturity *vs. Septoria* readings are highly significant. However, the fact that stem-break percentage was in part determined by three variables which were not independent makes it difficult to draw conclusions from table 1. For example, the significant correlation coefficient between stem-break percentage and *Septoria* readings was shown by means of part correlations[4] in table 2, to be due to the correlation between *Septoria* reading and maturity.

The part correlation coefficients in table 2 indicate that lodging resistance and maturity are about equally important in determining resistance to stem-break. This emphasizes the need to take stem-break readings within maturity classes or on comparable dates. When stem-break notes are

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[3] Grafius, J. E., and H. M. Brown. Lodging resistance in oats. Agron. Jour. 46:414–418. 1954.

[4] Ezekiel, Mordecai. The methods of correlation analysis. p. 183. John Wiley and Sons, Inc. New York, 1930.

taken for all varieties on the same date, an allowance must be made to compensate for the fact that the earlier maturity varieties have been standing in a dead ripe stage for a longer time.

Multiple regression statistics involving all four variables are given in table 3. The data in column 4 indicate that the 3 variables, lodging resistance, maturity and *Septoria* readings, accounted for from 28 to 36% of the variation in stem-break percentage.

DISCUSSION

In a previous article[5] the question was raised as to whether lodging resistance in the green plant was associated with stem-break in the senescent plant. The question is important both from the economic and theoretical standpoint. It is important to know if selection of lodging resistant varieties will also tend to give varieties which will stand for combine harvest. It also is important to isolate some of the factors involved in resistance to stem-break. In examining this relationship the effect of two other factors became apparent. It was found that relative maturity and amount of *Septoria* were correlated with stem-break.

Part correlation coefficients established the relationship between stem-break percentage *vs.* lodging resistance, maturity and *Septoria* readings. Lodging resistant varieties did tend to resist stem-break in senescence, but comparisons between varieties should either be made within maturity classes or the readings should be made in such a way as to compensate for the effects of differences in maturity.

It was shown further that the apparent relationship between stem-break percentage and *Septoria* readings was partly due to the correlation between maturity and *Septoria* readings. This is not to say that *Septoria* will not cause stem-break under more severe conditions.

Multiple regression coefficients showed that lodging resistance, maturity and *Septoria* readings accounted for from 28 to 36% of the variation in stem-break percentage.

SUMMARY

Lodging resistance is measured by the cL_r factor, maturity and, to a lesser extent, *Septoria avenae* readings were found to be correlated with stem-break percentage in senescence. In particular, it was found that there was a tendency for lodging resistant varieties of oats, as measured by the cL_r factor, to resist stem-break.

[5] Grafius and Brown, *op. cit.*

Table 1.—Simple correlation coefficients involving stem-break percentage, lodging resistance, maturity, and *Septoria avenae* readings on nurseries A and B.

Factor	Nursery	d.f.	Lodging resistance	Maturity	Septoria readings
Stem-break percentage	A	42	−0.424**	−0.388**	0.311*
	B	40	−0.410**	−0.484**	0.291
Lodging resistance	A	42	——	0.215	−0.275
	B	40	——	0.161	0.033
Maturity	A	42	——	——	−0.407**
	B	40	——	——	−0.532**

* $P < 0.05$.
** $P < 0.01$.

Table 2.—Part correlation coefficients for stem-break percentage (X_1) *vs.* lodging resistance (X_2), maturity (X_3), and *Septoria* readings (X_4).

Symbol*	Nursery	Coefficient
$_{12}r_{34}$	A	−0.356
	B	−0.391
$_{13}r_{24}$	A	−0.296
	B	−0.401
$_{14}r_{23}$	A	0.127
	B	0.129

* $_{12}r_{34}$ is the coefficient of part correlation of X_1 with X_2 where the effects of X_3 and X_4 have been removed.

Table 3.—Multiple regression statistics involving stem-break percentage, lodging resistance, date of heading and *Septoria* reading.

Nursery	R	R^2
A	0.530**	0.28
B	0.596**	0.36

** $P < 0.01$.

Frost Heaving of Seedlings in the Laboratory[1]

E. J. Kinbacher and Horton M. Laude[2]

FROST heaving, an uplifting of the soil surface caused by the formation of ice layers or lenses within the soil during freezing, may result in serious stand losses in regions where freezing and thawing are accompanied by conditions of high soil moisture.

Lamb (8) has considered heaving to be among the most common causes of injury to winter wheats in the Northeastern United States. Biswell *et al.* (4) reported that on California ranges, where freezing and thawing temperatures occur in the rainy season, heaving is a frequent cause of failure to obtain satisfactory stands of grasses and legumes on reseeded burned brushlands. Frischknecht (6) noted the importance of heaving as a cause of seedling mortality following melting of snow in the spring on Utah ranges. The losses from frost heaving incurred in forest nurseries were discussed by Jones and Peace (7) who directed attention to the lack of experimental work conducted on this phase of winter injury. Bayles and Taylor (2), with reference to breeding work for winter-hardiness, have pointed out the need for some practical method of measuring resistance to heaving. They state, "It has been possible to obtain reliable information on resistance of varieties to low temperatures both in field tests and with controlled temperature cabinets, but as yet a satisfactory technique has not been devised for determining, with controlled equipment, the relative resistance to heaving."

Certain information has been developed from both field and laboratory study pertaining to the principles and factors underlying the frost heaving of soil. Taber (9, 10) and Beskow (3) have studied the physical conditions affecting the frost heaving of soils in the laboratory. The former investigator considered the chief factors governing excessive soil lift to be availability of water, rate of freezing, and texture, consolidation, and composition of the soil. Most extensive frost heaving reportedly is associated with high levels of soil moisture, slow freezing or alternate freezing and thawing, and a fine-textured and well-compacted soil.

Bouyoucos and McCool (5) stressed that the heaving of soils is not due to mere expansion of water upon freezing, but rather to the growth during freezing of ice columns or ice layers from unfrozen water drawn to the freezing surface. The amount of soil surface uplift is essentially equal to the total thickness of the ice layers (10).

The importance of soil cover in influencing the time and depth of soil freezing has been stressed by Anderson (1) who compared bare soil with grass and brush cover, noting that a vegetative cover reduces both the depth of freezing in soil and the length of the winter freezing period.

[1] Contribution from the Department of Agronomy, University of California, Davis, Calif. Includes a portion of a thesis submitted by the senior author in partial fulfillment of the requirements for the Ph.D. degree at the University of California. Received April 11, 1955.

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Most studies of frost heaving in which plants have been considered have been based upon field observation made several weeks after the frost action has occurred, in some cases being made in the spring on plants heaved the previous autumn and winter. After such an interval of time, plant responses are considerably obscured by the numerous uncontrolled factors of the environment, and critical determination of the injury has been impossible. To the authors' knowledge, only one attempt to heave plants in the laboratory has been published (7), and in this instance insufficient soil lifts were obtained to permit study of the plant responses.

The objectives of the current research were first to develop a satisfactory procedure in the laboratory under controlled conditions to heave the seedlings of growing plants, and then to study critically the injuries induced by this frost heaving with a view toward clarifying the nature of heaving resistance. The former objective is treated in this report.

EXPERIMENTAL PROCEDURE

The laboratory techniques for heaving soils, developed by Taber (9, 10) and Beskow (3), supplied concepts which, when modified to permit plant growth, served as a basis for the development of the present method. These investigators were successful in producing frost heaving within freezing cabinets on cores of soil which during freezing were continuously supplied with water and were insulated with sand or cork powder except for the exposed upper surface.

In our studies, freezing temperatures were produced in a cold chamber having a floor area of 30 square feet, a volume of 150 cubic feet, and having the temperature of the circulating air thermostatically controlled within 2°F. of the desired setting (figure 1). Soil was packed in quart liquid-type cylindrical cardboard containers 8.5 cm. in diameter and 16 cm. high. Such cartons may be cut open easily for examination of plant roots when desired. The bottom of each carton was perforated with six small holes and covered with filter paper before being filled with soil. Filled cartons were wet by sub-irrigation, being set in a tray of shallow water in the greenhouse. This means of watering was used also during seedling growth after planting. To provide a source of reserve water during the freezing periods, each carton was set in a vessel 12 cm. in diameter and 8 cm. high containing a 2-inch depth of water. A masonite collar around the carton and resting on the lip of this water vessel prevented the entrance of the dry insulating sand in which the cartons and water vessels were packed during freezing periods with only the upper surface of the soil core exposed. It was found that the soil core froze from the top downward, and that the reserve water remained unfrozen during a 24-hour cold exposure when 6 inches of dry sand was placed beneath the water vessels for insulation and the carton centers were 6 inches from the sides of the wooden boxes containing the sand.

Humidity within the chamber was not controlled, and although the chamber was equipped with fluorescent lights, the heaving tests were conducted in darkness. Continuous records of air temperature 12 inches above the soil surface and of sand temperature at ½-inch depth were obtained on recording thermographs.

Twelve cartons of soil were frozen at a time, there being 6 in each of 2 wooden sand boxes. By successive repetition of each test, adequate numbers of heaved soil cores were obtained. In each carton 2 seedlings were tested, and for a comparison between 2 varieties or species, 1 seedling of each was used.

When more than two plants were grown per soil core, it became difficult to separate the root systems upon later examination. To insure two uniform seedlings without the necessity of planting additional seeds, sprouted seeds were planted. These were germinated on filter paper in Petri dishes in a seed germinator

and sown when the radicle was barely emerged from the seed coat. The age of planting was calculated from the time the seed was placed on moist filter paper. Seedlings were subjected to heaving when the roots had reached the bottom of the carton, this being at about the two-leaf stage. The age at initial testing varied somewhat depending upon the plant involved, being 14 days in the case of perennial ryegrass and Hardinggrass and 10 days for varieties of winter wheat.

Initial trials involved two 24-hour freezing periods separated by a 24-hour thawing interval. The air temperatures selected for the freezing exposures were 20° to 30°F. The following additional details were evolved from experiments using this general procedure.

RESULTS AND DISCUSSION

Five fine-textured California soils were compared for ability to frost heave under like conditions. These soils were Yolo fine sandy loam, Aiken, Chino, and Panoche clay loams, and Egbert muck. In tests in which the Aiken clay loam and Egbert muck lifted over 1 cm., the other soils lifted only a few millimeters. The frozen surface of the muck was loose and flaky and lacked noticeable ice segregation whereas that of the Aiken soil was firm and permeated with small ice layers. Aiken clay loam was used throughout the remainder of the tests. The source of soil for heaving studies was found to be very critical. After using soil procured near Paradise, Calif., Aiken clay loam from another site 20 miles from the first was tried. Though both soil lots appeared to be identical, that from the original source yielded consistent frost heaving while the other failed to heave at all.

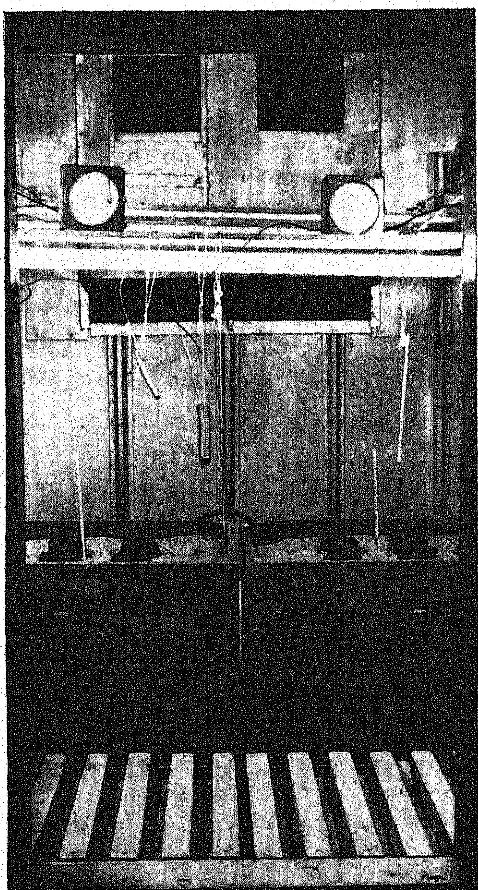

FIG. 1.—Interior of the cold temperature chamber in which frost heaving was produced.

The degree of uniformity of the soil when packed in the cartons appeared to be related to the amount of heaving obtained. Soil sifted through a screen having 1/4-inch mesh was compared with that passed through a 1/8-inch mesh, a 1.0 mm. screen, a 0.5 mm. screen, and soil pulverized with mortar and pestle. The pulverized soil was slowest to wet when set in water, and heaved the least when tested. That soil screened through the 1/8-inch mesh yielded the greatest uplift. In all trials, slowness of wetting was related to poor heaving. Likewise, soil cores which were set out of the water tray and permitted to dry somewhat supported reduced heaves compared to those continuously wet between the initial wetting and the heaving test. In the current studies, dry soil sifted through a screen of 1/8-inch mesh was firmly tamped into cartons with a wooden block, the cartons then being set in shallow water for 24 hours. Reduced irregularity of soil surface after freezing was obtained by depressing the surface 5 to 10 mm. with the finger tips at this time. Seed was then planted, the carton refilled with dry firmed soil, and set in the water tray until the test. Upon thawing after a freeze, the margins of the heaved soil tended to perch on the carton lip instead of settling to approximately the original level as did the soil away from the margin. Gentle depressing of this perched soil after thawing insured a relatively level soil surface following the next heave and did not injure the roots.

Both Beskow and Taber directed attention to the necessity of reducing friction between the soil core and container, and accomplished this in part by lubrication of the inner container surfaces. Comparison was made of several lubricants in our studies by using them to coat the inner top half of the cartons before packing with soil. Upon heaving, soil uplift among the cartons was found to be at least 1 cm. greater when chassis grease had been applied. This material produced no detectable effect upon the seedlings and was subsequently used in the preparation of cartons.

Beskow (3) demonstrated that frost heaving rate was independent of freezing rate. He recorded no difference in the rate of soil uplift between 14° and 28°F. This was confirmed by the authors who obtained analogous rates of soil rise at air temperatures of 20°, 26°, and 28°F., though as might be expected, heaving was initiated sooner at the lower temperatures.

The heaving tests with plants were run at a 28°F. air temperature. This temperature was preferable to a lower one as it permitted longer exposure of plants without cold injury to the tissues, and for a given duration of freeze, the soil core was frozen to a shallower depth with the ice layers being thicker and concentrated nearer the surface.

Cold hardening of the seedlings before a heaving trial undoubtedly would be desirable. Neither facilities nor time was available in these studies to develop a high level of hardiness. The greenhouse-grown seedlings were essentially unconditioned, being subjected only to 5 hours at 38°F. 2 days before the freeze and to 28°F. for 90 minutes the day before the test. Seedlings survived the 24-hour exposure to 28°F. with any visible cold injury usually confined to the basal leaf.

Measurements were made of soil lift and corresponding plant movement. Since the soil surface before heaving was level with the lip of the carton, direct measurement of the rise of the soil above the carton edge was possible after a freeze. Plant lift was more difficult to determine, since dur-

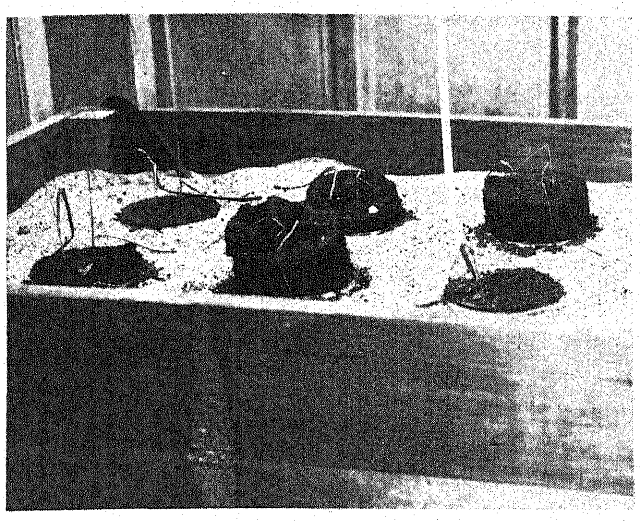

FIG. 2.—Six cartons in the insulating sand box after the second freeze. The rear left and front right cartons are controls. The four to the right are set over the heater.

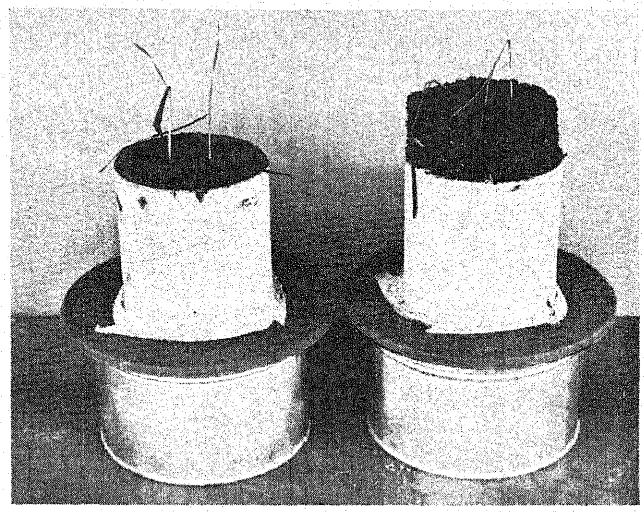

FIG. 3.—Control carton (left) and heaved carton (right) removed from sand box immediately following the second freeze. Soil had lifted 3.9 cm. at the base of the seedlings in the heaved carton.

ing heaving the soil often lifted more than the plant. This upward soil movement against the stem usually destroyed any marking on the plant at the soil level. Therefore, a dot of India ink was located for reference above the soil surface on first-leaf tissue which did not elongate during the freezing treatments. A millimeter scale was attached to a wooden rule which rested on the stationary sides of the sand box. Using this, any vertical movement of the plant from its original position could be noted, the uplift being attributed to frost heaving action.

Soil lifts in excess of 1 cm. often did not result in seedling injury. In an effort to obtain greater soil uplift, each freezing duration was extended from 24 to 48 hours. This did not increase soil rise, and careful examination revealed that by the end of 24 hours a thin ice film was forming over the base of the cartons. This ice prevented free passage of water to the zone of ice formation and checked soil lift. A source of heat under the cartons was provided by a 7½-watt bulb enclosed in a shallow metal box on which 4 cartons with reserve water vessels could be set. The electric bulb, operated through a time switch, was on frequently enough to prevent icing of the carton bases. The 48-hour freezes at 28°F. then consistently produced soil rises of 1 to 2 cm., and frequently lifts of 3 to 4 cm. were obtained. Soil surface uplift commenced 9 to 10 hours after starting the freeze. At the end of 48 hours the soil core was frozen to a depth of approximately 1¼ inches below the lip of the carton, and sand temperature at depths of ½ and 2½ inches was near 29° and 34°F., respectively. With this greater soil uplift, the proportion of plants with tissue breakage was increased, 48% of all Hardinggrass seedlings tested being so injured.

Two of the 6 cartons in each sand box were controls in which heaving was prevented by the degree of dryness of the soil. These cartons were removed from the water tray 5 to 6 days before a test, and during the freeze the reserve water vessel under them was dry. In other respects the control plants were subjected to conditions identical with those of plants to be heaved. In figure 2 the front right and rear left cartons are controls, the former being seated over the heater which had no effect on soil uplift of the control. Of the four cartons heaved, the front left is not set on the heater and soil movement is reduced. A comparison of a heaved carton with a control carton removed from the sand box immediately after the second freeze is seen in figure 3. The control seedlings continued growth.

To identify the moisture conditions used, additional cartons were prepared for some tests and moisture determinations were made on soil 1 inch below the surface. The moisture equivalent of the Aiken clay loam used was 32.2%. Soil moisture on a dry weight basis averaged 54.5% in cartons to be heaved, thus being well over field capacity. In control cartons moisture ranged from 24.1 to 37.6%. Controls from those lots above the moisture equivalent were found to support heaves of a few millimeters, though the surface was loose and powdery and the seedlings were not lifted. Soil moisture well above field capacity appears necessary for the development of appreciable frost heaving.

SUMMARY

A laboratory procedure is described which was developed to produce frost heaving in soils during the growth of young seedlings.

Soil surface uplift as great as 3 to 4 cm. was obtained on soil cores 16 cm. long in a cold temperature chamber using two 48-hour exposures to air temperature at 28°F. separated by a 24-hour thawing interval. The winter wheat and perennial grass seedlings tested at 10 to 14 days of age survived the cold. Tissue breakage attributable to heaving was produced in 48% of all Hardinggrass seedlings tested. The method permits critical study of the effects of frost heaving on seedling plants.

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A Summary of Linkage Studies in Barley: Supplement II, 1947-1953[1]

D. W. Robertson, G. A. Wiebe, and R. G. Shands[2]

SINCE the publication of "A Summary of Linkage Studies in Barley," by Robertson, Wiebe, and Shands (16), several papers on linkage and genetic studies in barley have been published. In the present paper, an attempt will be made to bring the linkage data up to date. A list of characters recently studied by various workers in barley genetics and chromosome maps for the linkage groups are given.

Genetic Factors

Some of the previously reported characters seem to be controlled by similar genes, and in these cases one symbol is given to represent such characters (table 1). While the gene difference for some of these characters may not be proved, the similarity of characters and location of genes on the chromosome indicate that the genes may be the same. In several cases, different parents have been used, and the characters described are similar; however, no test has been made to determine if their expression is due to the interaction of the same gene. To simplify the nomenclature, many of the previously reported symbols will be dropped and one symbol used.

New Symbols Allotted

Several new characters have been described in genetic studies made since 1946. Smith (20) has summarized the genetic literature, describing characters and allotting symbols to many genes not listed by Robertson and co-workers (15, 16). Table 2 presents a list of symbols allotted to the various characters not previously discussed or where changes have been made in the symbols. The authors would be pleased to receive suggested symbols for new characters being studied in order to check them against the symbols already assigned and prevent duplication.

In showing the linkage map, only genes which have been found linked with two or more other genes will be shown. Since the publication of Smith (20), several additional genes have been added to Group I. In some cases the order of the genes on the map is different from that presented by Smith (20).

LINKAGE GROUP I

lr
lk y^x
tr li p_c *v pr rin g re2 h e f y lg or*

The factor pairs located in linkage group I are as follows: normal vs. triple-awned lemma, *Tr tr* (16, 20); normal vs. liguleless, *Li li* (24)[3]; purple-veined vs. white lemma, P_c p_c (15, 20); *v*, *lk*, and *lr*, a series of multiple alleles; non-six-row vs. six-row, *Vv* (15); awned vs. awnless, *Lk lk;* normal vs. reduced lateral spikelet appendage on the lemma, *Lr lr* (16); purple vs. nonpurple stem, *Pr pr* (15, 20, 22); lax vs. dense, *Rin rin* (16); toothed vs. untoothed lemma, *Gg* (8, 15, 20); purple vs. nonpurple pericarp and lemma or red vs. yellow pericarp, *Re2 re2* (15, 30)[4], the latter being one of the complementary gene pairs for purple color of the pericarp; tall vs. short, *Hh* (15); normal vs. long-awned glume, *Ee* (16), possibly the same factor pair as wide vs. narrow glume, *Ww* (15); normal vs. chlorina plant color, *Ff* (15, 16); normal vs. virescent or yellow seedlings, multiple alleles *Y* $y^x y$ (16); green vs. light-green seedlings, *Lg lg* (16); and green vs. orange seedlings, *Or or* (16). Several lax vs. dense spike factor pairs have been located by various workers on linkage group I (15).

The crossover values obtained by various workers, which are not reported by Robertson and co-workers (15, 16), are presented in table 3.

Table 1.—Genetic factors which may express the same character.

Character	Recommended symbol	Previous symbol used	Authority*
Normal vs. long-awned glume	*Ee*	*Ww*, *Log log*	15
Purple vs. nonpurple grain (Complementary factors)	*Re re*	*Pp*, *Re re*, *Pl pl*	15, 20, 30
Resistance vs. susceptibility to mildew	Ml_g ml_g	Ml_{cp} ml_{cp}	2, 20

* Literature Cited.

[1] Contribution from the Department of Agronomy, Colorado Agr. Exp. Sta., Fort Collins, Colo.; the Field Crops Research Branch, A.R.S., U.S.D.A.; and the Department of Agronomy, Wisconsin Agr. Exp. Sta., Madison, Wis., cooperating.

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[2] Chief Agronomist, Colo. Agr. Exp. Sta.; Principal Agronomist, U.S.D.A.; and Senior Agronomist, U.S.D.A. and Wis. Agr. Exp. Sta., respectively.

[3] Schooler, A. B. A study of the possible location of the liguleless (auricle-less) gene in linkage group I in cultivated barley. M.Sc. thesis, Colorado A. & M. Col. 1952.

[4] Smith, H. S. The inheritance of seed color in the cross *Hordeum intermedium cornutum* × *Hordeum distichon nudum*. M.Sc. thesis, Colorado A. & M. Col. 1951.

A multiple allelic series is described by Woodward (29) for the inheritance of fertility of the lateral florets, v, V^d, V, V^t. This series reacts with the I^h, I, i series in linkage group IV to give different degrees of fertility of the lateral florets.

All Vv or V^dv genotypes are characterized in F_1 by considerable development of the lateral florets and lemma awns. These laterals are relatively infertile in the presence of ii but show considerable to almost complete fertility when either I^hI^h or II combinations accompany the heterozygous Vv genotype.

VV, V^dV, and V^dV^d genotypes have no awns on the laterals regardless of the I alleles present. Lateral floret and kernel development is more pronounced with V^d than with V genotypes.

With few exceptions, all V^tv, V^tV and V^tV^d F_1 plants appear very much like the V^tV^t deficiens parent having reduced lateral florets with no apparent sex organ, lateral awn, or beak development. In a few crosses the heterozygote could be classified as a weak two-rowed type having lateral florets similar to Nudideficiens while in others the laterals were even stronger.

Table 2.—New symbols allotted since 1946 to genetic characters.

Character	Recommended symbol	Previous symbol used	Authority*
Normal vs. branched ear	*Be be*	*Nb*	20
Normal vs. branched ear, second factor	*Be2 be2*	Nb_1	20
Brown yellow vs. white lemma	*Bg bg*	*Gg*	15, 26
Third factor for brittle rachis	*Bt3 bt3*	—	20
Awned vs. dehiscent awn	*Da da*	$Lk_u\ lk_u$	15, 20
Awned vs. dehiscent awn, second factor	*Da2 da2*	—	20
Early vs. late maturity, second factor	*Ea2 ea2*	—	20
Early vs. late maturity, third factor	*Ea3 ea3*	—	20
Erectoides	14 different loci involved	—	3
Normal vs. fragile stem	*Fs fs*	—	24
Resistance vs. susceptibility to greenbug	*Grb grb*	—	†
Resistance vs. susceptibility to greenbug	*Grb2 grb2*	—	†
Resistance vs. susceptibility to greenbug	*Grb3 grb3*	—	†
Tall vs. short	*H2 h2*	—	20
Complementary factor inhibiting red pericarp color	*J2 j2*	$J_1\ j_1$	15, 20
Normal hood vs. elevated hood	$K\ K^e$	—	24
Heavy vs. light kernels (several factors)	*Kw kw*	—	20
Hooded vs. long-awned	*Kl2 kl2*	$Kl_1\ kl_1$	15, 20
Lax vs. dense spike	*L2 l2*	$L_1\ l_1$	15, 20
Lax vs. dense spike	*L3 l3*	$L_2\ l_2$	15, 20
Lax vs. dense spike	*L4 l4*	$L_3\ l_3$	15, 20
Lax vs. dense spike	*L5 l5*	$L_4\ l_4$	15, 20
Lax vs. dense spike	*L6 l6*	$L_5\ l_5$	15, 20
Lax vs. dense spike	$L_c\ l_c$	—	‡
Lax vs. dense spike	$L_d\ l_d$	—	‡
Normal vs. long basal internode	*Lb lb*	*Bi bi*	6
Normal vs. liguleless	*Li li*	*Al al*	24, §
Series of factors for awn length	*Lk4 lk4 Lk5 lk5*	—	13
Susceptibility vs. resistance to mildew	$Ml_c\ ml_c$	—	20
Susceptibility vs. resistance to mildew	$Ml_m\ ml_m$	—	20
Resistance vs. susceptibility to mildew	$Ml_n\ ml_n$	—	20
Resistance vs. susceptibility to mildew	$Ml_w\ ml_w$	—	20
Resistance vs. susceptibility to nonparasitic leaf spot	$N_p\ n_p$	—	14
Purple vs. nonpurple lemma	*P2 p2*	$P_1\ p_1$	15, 20
Purple vs. nonpurple lemma	*P3 p3*	$P_2\ p_2$	15, 20
Resistance vs. susceptibility to *Puccinia anomala*	*Pa pa*		7, 16
Rough vs. smooth awn	*R2 r2*	$R_1\ r_1$	15, 20
Rough vs. smooth awn	*R3 r3*	$R_2\ r_2$	15, 20
Rough vs. smooth awn	*R4 r4*	$R_3\ r_3$	15, 20
Spring vs. winter habit	*Sh sh*	—	20
Spring vs. winter habit	*Sh2 sh2*	—	20
Spring vs. winter habit	*Sh3 sh3*	—	20
Spring vs. winter habit (light sensitive)	*Shs shs*	*Ls ls*	22, 25
Normal vs. subjacent hood	*Sk sk*	—	24
Breaking strength of straw	*Sts sts*	—	16
Normal vs. unbranched style	*U2 u2*	$U_1\ u_1$	15, 20
Normal vs. unbranched style	*U3 u3*	$U_2\ u_2$	15, 20
Normal vs. branchless stigma	*U4 u4*	—	23
Resistance vs. susceptibility to *Ustilago nuda*	*Un3 un3*	—	17
Resistance vs. susceptibility to *U. nuda*	*Un4 un4*	—	17
Resistance vs. susceptibility to *U. nuda*	*Un5 un5*	—	17
Resistance vs. susceptibility to *U. nuda*	*Un6 un6*	*Ts ts*	19
Normal vs. "uzu"	*Uz uz*	—	21
Waxy bloom on head and sheath vs. normal	*Wh2 wh2*	$Wh_1\ wh_1$	15, 20

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Table 3.—Linkages and associations not reported in linkage group I in previous summaries (15, 16).

Character	Recommended symbol	Previous symbol used	Percentage recombination	Authority*
Non-six-rowed vs. six-rowed (*Vv*) in relation to:				
Brownish-yellow vs. white lemmas	*Bg bg*	*Gg*	38.6	26
Normal vs. long-awned glumes	*Ee*	——	27.6	24
Heavy vs. light kernels (kernel wt.)	*Kw kw*	——	Correlated	20
Lax vs. dense	*L l*	——	Correlated	20
Normal vs. liguleless	*Li li*	*Al al*	38.9	24
Normal vs. liguleless	*Li li*	——	40–42	†
Normal vs. male sterile	*Ms2 ms2*	——	Correlated	20
Resistance vs. susceptibility to *Puccinia anomala*	*Pa pa*	——	Correlated	7
Purple vs. white straw	*Pr pr*	——	8.4	24
Purple vs. white straw	*Pr pr*	——	10.1	28
Complementary factors for purple vs. nonpurple lemma and pericarp	*Re2 re2*	*Pp*	4–18	30
Normal vs. tweaky spike	*Tw tw*	——	Correlated	‡
Normal vs. long-awned glumes (*Ee*) in relation to:				
Toothed vs. untoothed lemma	*Gg*	——	13–41	8
Normal vs. liguleless	*Li li*	*Al al*	50.6	24
Purple vs. white straw	*Pr pr*	——	34.0	24
Normal vs. liguleless (*Li li*) in relation to:				
Purple vs. white straw	*Pr pr*	——	30.4	24
Green vs. chlorina seedling (*Ff*) in relation to:				
Normal vs. liguleless	*Li li*	*Al al*	50.4	†

† Schooler, A. B. A study of the possible location of the ligule-less (auricle-less) gene in linkage group I in cultivated barley. M. Sc. thesis, Colo. A. & M. Col., 1952.
‡ Robertson, D. W. Unpublished data.
* Literature Cited.

Table 4.—Linkages and associations not reported in linkage group II in previous summaries (15, 16).

Character	Recommended symbol	Previous symbol used	Percentage recombination	Authority*
Black vs. white lemma and pericarp (*Bb*) in relation to:				
Normal vs. brittle rachis	*Bt bt*	——	26.5	27
Complementary factor pairs for purple vs. nonpurple lemma and pericarp	*Re re*	*Cc*	14–31	30
Normal vs. third outer glume	*Trd trd*	——	11.0	9
Normal vs. third outer glume	*Trd trd*	(bracteate)	14.8	24

* Literature Cited.

All plants carrying *vv* genes regardless of their accompanying *I* alleles are six-rowed and for the most part are fully fertile.

The V^tV^t genotype (White Deficiens, C. I. 7140) is a deficiens phenotype regardless of which *I* alleles are present. The I^h, I, i alleles are entirely hypostatic to V^tV^t as in *vv* genotypes.

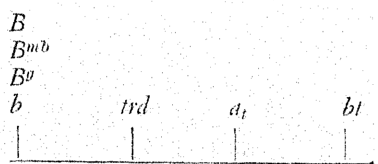
VV or V^dV^d genotypes in the presence of *ii* prevent the development of lateral ovules and awns or hoods on lateral florets. The genotype for Svanhals (C. I. 187) is $V^dV^d\ ii$ and for *Hordeum deficiens nudideficiens* (C. I. 2229), *VVii.*

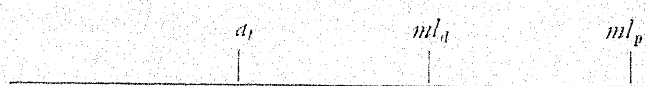
The intermedium factor *I*, which may be regarded as a factor for fertility, is able to carry the development of laterals only part of the way, the laterals being infertile and with rounded lemmas in *II* or *Ii* genotypes. Under certain growing conditions from 1 to 3 undersized lateral kernels per head may be found in the *II* genotypes as in *H. distichon nigrinudum* (C. I. 2222) *VVII.*

The I^h factor which is an allele for high fertility produces partial fertility ranging from 5 to 60% in the VVI^hI^h genotype. When associated with *VV* neither I^h nor *I* produces as strongly developed lateral florets as when associated with V^dV^d.

Linkage Group II

The factor pairs located in linkage group II are presented below:





The following factor pairs are located on the chromosome map. The allelic series for lemma and pericarp colors: black vs. white lemma and pericarp, *Bb* (15); gray vs. white lemma and pericarp, B^gb^g (16); medium black vs. white lemma and pericarp, $B^{mb}b^{mb}$ (16); normal vs. third outer glume, *Trd trd* (9, 15, 24); normal vs. white seed-

Table 5.—Linkages and associations not reported in linkage group IV in previous summaries (15, 16).

Character	Recommended symbol	Previous symbol used	Percentage recombination	Authority*
Hooded vs. awned (*Kk*) in relation to:				
Early vs. late	*Ea2 ea2*	———	20	20
Long vs. short-awned	*Lk5 lk5*	———	6.9	13
Lax vs. dense spike	*L l*	———	Correlated	†
Rachis internode number	*Rin2 rin2*	———	Correlated	20
Normal vs. light-green seedling	*Lg3 lg3*	———	10.5	4, 5
Res. vs. susceptibility to mildew race 4	$Ml_g\ ml_g$	———	16.0	2
Blue vs. nonblue aleurone (*Bl bl*) in relation to:				
Hooded vs. awned	*Kk*	———	21.8	24
Elevated hood vs. awned	$K^e k$	———	23.5	24

† Ostler, R. D. Inheritance of rachis length in crosses of accordian rachis. Colo. A. & M. Col., M. Sc. thesis, 1949.
* Literature Cited.

Table 6.—Linkages and associations not reported in linkage group V in previous summaries (15, 16).

Character	Recommended symbol	Previous symbol used	Percentage recombination	Authority*
Rough vs. smooth awn (*Rr*) in relation to:				
Early vs. late heading	*Ea3 ea3*	*Ea ea*	Correlated	15, 20
Normal vs. fragile stem	*Fs fs*	———	38.6	24
Lax vs. dense spike	$L_a\ l_a$	———	Correlated	†
Long vs. short basal spike internode	*Lb lb*	———	16	6, 20
Long vs. short-haired rachilla	*Ss*	———	25–26	24
Long vs. short-haired rachilla (*Ss*) in relation to:				
Normal vs. fragile stem	*Fs fs*	———	20–26	22, 24
Hairy vs. nonhairy rachis	*Hr hr*	———	23	27, 20
Lax vs. dense spike	*L l*	———	Correlated	‡
Lax vs. dense spike	$L_a\ l_a$	———	Correlated	†
Long vs. short basal spike internode	*Lb lb*	*Bi bi*	40	6, 20
Branched vs. unbranched style (3 factors)	*U u*	———	Correlated	15
Lax vs. dense spike (*L3 l3*) in relation to:		$L_2\ l_2$		
Long vs. short-haired rachilla	*Ss*	———	29.3	6
Rough vs. smooth awn	*R2 r2*	———	34.7	6

† Webster, O. J. Genetics and morphology of rachis internode length in barley. Univ. of Minn., Ph. D. thesis, 1950.
‡ Ostler, R. D. Inheritance of rachis length in crosses of accordian rachis, Colo. A. & M. Col., M. Sc. thesis, 1949.
* Literature Cited.

lings in Trebi I, $A_t a_t$ (15); normal vs. brittle rachis, *Bt bt* (27). Two other genes have been located on the map, but their relationship to the *Bb* factor pairs has not been determined; namely, susceptibility vs. resistance to mildew race 3, $Ml_a\ ml_a$ (16) and resistance vs. susceptibility to mildew race 3, $Ml_p\ ml_p$ (16).

Linkage Group III

In recent studies with interchanges, Kramer and co-workers (10) have indicated that linkage groups formerly designated as III and VII should be considered as one. Therefore, linkage group III will be discussed with linkage group VII.

Linkage Group IV

The genes located in linkage group IV are presented below:

I^h K
I K^e
i k $lg4$ z $lg3$ gl $gl2$ ml_g bl

The following factor pairs are located in linkage group IV: the allelic series I^h, I, i (15); fertile intermedium vs. nonintermedium, $I^h i$ (15); infertile intermedium vs. nonintermedium, *Ii* (15); hooded vs. awned, *Kk* (15, 24); elevated hood vs. awned, $K^e k$ (24); normal vs. light-green seedling, *Lg4 lg4* (16); normal vs. zoned leaf, *Zz* (16); normal vs. light-green seedling, *Lg3 lg3* (4, 5); normal vs. glossy seedling, *Gl gl* (16); normal vs. glossy seedling, *Gl2 gl2* (16); resistance vs. susceptibility to mildew, $Ml_g\ ml_g$, using race 3 (16) and race 6 (6); and blue vs. nonblue aleurone, *Bl bl* (15).

Linkage Group V

The factor pairs located in linkage group V are presented below:

lb r $l3$ s fs

The following factor pairs are located in linkage group V: long vs. short basal spike internode, *Lb lb* (6, 20); rough vs. smooth awn, *Rr* (15); lax vs. dense spike, *L3 l3* (15); long vs. short-haired rachilla, *Ss* (15); and normal vs. fragile stem, *Fs fs* (24).

The crossover percentages and associations of factor pairs not reported in linkage group V in previous summaries (15, 16) are presented in table 6.

Table 7.—Linkage and associations of factor pairs not reported in linkage group VI in previous summaries (15, 16).

Character	Recommended symbol	Previous symbol used	Percentage recombination	Authority*
Normal vs. "*uzu*" (*Uz uz*) in relation to:				
Green vs. white seedlings in Nigrinudum I	$A_n\ a_n$	———	15.8	21
Green vs. white seedlings in Colsess I	$A_c\ a_c$	———	10.7	21
Green vs. xantha seedlings ($X_c\ x_c$) in Colsess IV in relation to:				
Lax vs. dense spike	$L_c\ l_c$	———	1.3	†
Normal vs. xantha seedlings ($X_s\ x_s$) in Smyrna I in relation to:				
Lax vs. dense spike	$L_c\ l_c$	———	Correlated	†

* Literature Cited.
† Webster, O. J. Genetics and morphology of rachis internode length in barley. Ph. D. thesis, Univ. of Minnesota, 1950.

Table 8.—Linkage and associations of factor pairs not reported in linkage group III in previous summaries (15, 16).

Character	Recommended symbol	Previous symbol used	Percentage recombination	Authority*
Covered vs. naked caryopsis (*N n*) in relation to:				
Late vs. early	*Ea4 ea4*	———	Correlated	12
Tall vs. short	*H h*	———	11	20
Lax vs. dense spike	*L l*	———	9.4	24
Normal vs. long chromosome	*Lc lc*	———	Linked	†
Long vs. short awn	*Lk lk*	———	8.8	24
Long vs. short style branches	*U4 u4*	———	8	23
Large vs. small number of vascular bundles	*Vb vb*	———	Correlated	11
Lax vs. dense spike (*L l*) in relation to:				
Long vs. short awn	*Lk lk*	———	18.4	24
Long vs. short awn	*Lk lk*	———	25	23

* Literature Cited.
† McLennan, H. A. Cytogenetic studies of a strain of barley with long chromosomes. M. Sc. thesis, Univ. of Minnesota. 1947.

Table 9.—Linkage and associations of factor pairs not reported in linkage group VII in previous summaries (15, 16).

Character	Recommended symbol	Previous symbol used	Percentage recombination	Authority*
Resistance vs. susceptibility to stem rust (*T t*) in relation to:				
Resistance vs. susceptibility to loose smut	*Un un*	———	Close	18
Normal green vs. chlorina seedlings ($F_c\ f_c$) in Colsess V in relation to:				
Normal vs. waxy endosperm	*Wx wx*	———	1.5	†

* Literature Cited.
† Webster, O. J. Genetics and morphology of rachis internode length in barley. Ph. D. thesis, Univ. of Minnesota, 1950.

Table 10.—Miscellaneous linked factor pairs.

Character	Recommended symbol	Previous symbol used	Percentage recombination	Authority*
Spring vs. winter habit, light sensitive (*Shs shs*) in relation to:	*Shs shs*	*Ls ls*		
Hairy vs. nonhairy leaf sheath	*Hs hs*	———	6.4	22, 25
Long vs. short awn (*Lk4 lk4*) in relation to:				
Lax vs. dense spike	*L l*	———	19.3	13

* Literature cited.

Linkage Group VI

The factor pairs located in linkage group VI are presented below:

The following factor pairs are located in linkage group VI: normal vs. *uzu*, *Uz uz* (21); normal vs. white seedlings in Colsess I, $A_c\ a_c$ (15); normal vs. xantha seedlings in Colsess IV, $X_c\ x_c$ (15); lax vs. dense spike, $L_c\ l_c$[5];

[5] Webster, O. J. Genetics and morphology of rachis internode length in barley. Ph.D. thesis, Univ. of Minn. 1950.

Table 11.—Factor pairs showing independent inheritance as reported by workers on barley genetics from 1946 to 1953.

Linkage groups	Recommended symbol	Previous symbol used	Authority*
Non-six-row vs. six-rowed (*Vv*) independent of:			
Normal vs. brittle rachis	*Bt bt*	———	27
Normal vs. fragile stem	*Fs fs*	———	24
Susceptibility vs. resistance to *Helminthosporium sativum*	*Hl hl*	———	1
Lax vs. dense spike	*L l*	———	13
Long vs. short awn	*Lk4 lk4*	———	13
Long vs. short awn	*Lk5 lk5*	———	13
Resistance vs. susceptibility to mildew	$Ml_{g}\ ml_{g}$	$Ml_{cp}\ ml_{cp}$	2
Normal vs. third outer glume	*Trd trd*	———	24
Normal vs. "*uzu*"	*Uz uz*	———	21
Resistance vs. susceptibility to *Ustilago nuda*	*Un3 un3*	———	17
Normal vs. liguleless (*Li li*) independent of:			
Normal vs. "*uzu*"	*Uz uz*	———	21
Normal vs. reduced lateral awns (*Lr lr*) independent of:			
Long vs. short awns	*Lk4 lk4*	———	13
Long vs. short awns	*Lk5 lk5*	———	13
Lax vs. dense spike	*L l*	———	13
Black vs. white lemma and pericarp (*Bb*) independent of:			
Normal vs. fragile stem	*Fs fs*	———	24
Susceptibility vs. resistance to *H. sativum*	*Hl hl*	———	1
Lax vs. dense spike	*L l*	———	†
Lax vs. dense spike	*L l*	———	13
Normal vs. liguleless	*Li li*	*Al al*	24
Long vs. short awn	*Lk4 lk4*	———	13
Long vs. short awn	*Lk5 lk5*	———	13
Resistance vs. susceptibility to mildew	$Ml_{g}\ ml_{g}$	$Ml_{cp}\ ml_{cp}$	2
Resistance vs. susceptibility to *U. nuda*	*Un3 un3*	———	17
Resistance vs. susceptibility to *U. nuda*	*Un4 un4*	———	17
Resistance vs. susceptibility to *U. nuda*	*Un5 un5*	———	17
Normal vs. "*uzu*"	*Uz uz*	———	21
Covered vs. naked caryopsis (*Nn*) independent of:			
Normal vs. brittle rachis	*Bt bt*	———	27
Normal vs. fragile stem	*Fs fs*	———	24
Susceptibility vs. resistance to *H. sativum*	*Hl hl*	———	1
Lax vs. dense spike	*L l*	———	†
Normal vs. liguleless	*Li li*	*Al al*	24
Long vs. short awn	*Lk5 lk5*	———	13
Resistance vs. susceptibility to mildew	$Ml_{g}\ ml_{g}$	$Ml_{cp}\ ml_{cp}$	2
Normal vs. third outer glume	*Trd trd*	———	24
Resistance vs. susceptibility to *U. nuda*	*Un3 un3*	———	17
Normal vs. "*uzu*"	*Uz uz*	———	21
Long vs. short awn (*Lk lk*) independent of:			
Normal vs. fragile stem	*Fs fs*	———	24
Normal vs. liguleless	*Li li*	*Al al*	24
Normal vs. "*uzu*"	*Uz uz*	———	21
Lax vs. dense spike (*L l*) independent of:			
Normal vs. fragile stem	*Fs fs*	———	24
Normal vs. liguleless	*Li li*	*Al al*	24
Normal vs. "*uzu*"	*Uz uz*	———	21
Hooded vs. awned (*Kk*) independent of:			
Susceptibility vs. resistance to *H. sativum*	*Hl hl*	———	1
Lax vs. dense spike	*L l*	———	†
Long vs. short awn	*Lk4 lk4*	———	13
Resistance vs. susceptibility to *U. nuda*	*Un3 un3*	———	17
Normal vs. unbranched stigma	*U4 u4*	———	23
Long vs. short awn (*Lk5 lk5*) independent of:			
Long vs. short awn	*Lk4 lk4*	———	13
Blue vs. nonblue aleurone (*Bl bl*) independent of:			
Normal vs. brittle rachis	*Bt bt*	———	27
Normal vs. fragile stem	*Fs fs*	———	24
Normal vs. liguleless	*Li li*	*Al al*	24
Normal vs. reduced lateral awns	*Lr lr*	———	13
Long vs. short awns	*Lk4 lk4*	———	13
Normal vs. "*uzu*"	*Uz uz*	———	21
Rough vs. smooth awn (*Rr*) independent of:			
Lax vs. dense spike	*L l*	———	13
Lax vs. dense spike	*L l*	———	†
Susceptibility vs. resistance to *H. sativum*	*Hl hl*	———	1
Long vs. short awn	*Lk4 lk4*	———	13
Normal vs. liguleless	*Li li*	*Al al*	24
Resistance vs. susceptibility to mildew	$Ml_{g}\ ml_{g}$	$Ml_{cp}\ ml_{cp}$	2
Resistance vs. susceptibility to *U. nuda*	*Un4 un4*	———	17
Resistance vs. susceptibility to *U. nuda*	*Un5 un5*	———	17
Resistance vs. susceptibility to *U. nuda*	*Un un*	———	17
Normal vs. "*uzu*"	*Uz uz*	———	21

Table 11.—Factor pairs showing independent inheritance as reported by workers on barley genetics from 1946 to 1953—continued.

Linkage groups	Recommended symbol	Previous symbol used	Authority*
Long vs. short-haired rachilla (*Ss*) independent of:			
Susceptibility vs. resistance to *H. sativum*	*Hl hl*	—	1
Normal vs. liguleless	*Li li*	*Al al*	24
Normal vs. third outer glume	*Trd trd*	—	24
Normal vs. unbranched stigma	*U4 u4*	—	23
Resistance vs. susceptibility to *U. nuda*	*Un un*	—	17
Resistance vs. susceptibility to *U. nuda*	*Un4 un4*	—	17
Long vs. short-haired rachilla (*Ss*) independent of:			
Resistance vs. susceptibility to *U. nuda*	*Un5 un5*	—	17
Normal vs. "*uzu*"	*Uz uz*	—	21
Normal vs. fragile stem (*Fs fs*) independent of:			
Normal vs. "*uzu*"	*Uz uz*	—	21
Normal vs. "*uzu*" (*Uz uz*) independent of:			
Normal vs. unbranched stigma	*U4 u4*	—	23
Normal vs. xantha seedlings ($X_e\ x_e$) independent of:			
Susceptibility vs. resistance to *H. sativum*	*Hl hl*	—	1
Long vs. short awn	*Lk4 lk4*	—	13
Normal vs. white seedlings ($A_e\ a_e$) independent of:			
Normal vs. liguleless	*Li li*	*Al al*	24
Normal vs. white seedlings ($A_n\ a_n$) independent of:			
Normal vs. third outer glume	*Trd trd*	—	24
Green vs. chlorina ($F_e\ f_e$) independent of:			
Lax vs. dense	*L l*	—	†
Normal vs. "*uzu*"	*Uz uz*	—	21
Normal vs. brachytic (*Br br*) independent of:			
Normal vs. fragile stem	*Fs fs*	—	24
Normal vs. liguleless	*Li li*	*Al al*	24
Green vs. virescent seedlings ($Y_e\ y_e$) independent of:			
Normal vs. "*uzu*"	*Uz uz*	—	21
Resistance vs. susceptibility to stem rust (*Tt*) independent of:			
Susceptibility vs. resistance to *H. sativum*	*Hl hl*	—	1
Normal vs. short awns on the glumes ($E_2\ e_2$) independent of:			
Susceptibility vs. resistance to *H. sativum*	*Hl hl*	—	1

* Literature Cited.
† Ostler, R. D. Inheritance of rachis length in crosses of accordian rachis. Colo. A. & M. Col., M. Sc. Thesis, 1949.

normal vs. white seedlings in Nigrinudum I, $A_n\ a_n$ (15); and normal vs. xantha seedlings in Smyrna I, $X_s\ x_s$ (15).

The crossover percentages and associations of factor pairs not reported in linkage group VI in previous summaries (15, 16) are given in table 7.

Linkage Groups III and VII

In recent studies on interchanges, Kramer and co-workers (10) have indicated that groups III and VII may be on the same chromosome. The relationships of the genes, however, are not definitely determined in relation to each other. The linkage groups of both chromosomes are given below under the old designations.

	n	$bl\ 2$	rs	a_{c2}
Group III	|	|	|	|

	t	br	f_c	wx	y_c
Group VII	|	|	|	|	|

The symbols of group III represent the following factor pairs: covered vs. naked caryopsis, *Nn* (15); blue vs. non-blue aleurone (second factor pair), *Bl2 bl2* (16); red stem vs. green stem, *Rs rs* (16); and normal vs. white seedlings in Coast II, $A_{c2}\ a_{c2}$ (15). The following factor pairs have been located in linkage group VII: resistance vs. susceptibility to *Puccinia graminis tritici*, *Tt* (15); normal vs. brachytic, *Br br* (15); normal vs. chlorina seedlings in Colsess V, $F_c\ f_c$ (16); normal vs. waxy endosperm, *Wx wx* (20); and normal vs. virescent seedlings in Coast III, $Y_c\ y_c$ (15).

The crossover percentages and associations of factor pairs not reported in linkage group III in previous summaries (15, 16) are given in table 8.

The crossover percentages and associations of factor pairs not reported in linkage group VII in previous summaries (15, 16) are given in table 9.

Several factor pairs have been found to be linked with each other but not with genes already located in the different linkage groups. Table 10 presents the miscellaneous factor pairs not located in any definite group.

Arny (1) found a possible association of *Helminthosporium sativum* susceptibility with *H. gramineum* resistance.

The character pairs which showed independent inheritance in various groups studied are listed in table 11.

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Effect of Fiber Irregularity on Spinning Performance[1]

D. M. Simpson, C. B. Landstreet, and E. N. Duncan[2]

THE term "uniform" as applied to a cotton variety by a breeder implies that all plants conform closely to a fixed standard in all measurable characteristics and that the genetic composition of the variety has been stabilized. The importance of uniformity has been stressed in cotton breeding programs, and line breeding has had as a main objective the selection of strains that are homozygous for plant and fiber characters.

Recent investigations in breeding methodology have indicated that inbreeding may result in greater uniformity, but such increase in uniformity may be associated with loss in vigor and lower yields. On the other hand, hybridization of good combining lines has resulted in increased vigor and larger yields in the early generations of such hybrids. It is to be expected that the product from segregating generations of hybrids will be less uniform than that from line bred varieties. Thus, emphasis upon uniformity may deter breeders from using methods that otherwise would seem advantageous. More information is needed on the spinning performance of cottons that differ in uniformity of fiber properties so that the allowable limits of variation in these properties may be more accurately defined.

Cotton samples are never uniform in the sense that all fibers are of equal length, strength, or fineness even on the same plant or on an individual seed. In current methods

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of measuring fiber properties, a composite mass of fibers is normally employed and the measurements are reported as means or modal values. The mixing of seed of different varieties, changing environmental conditions during the period of growth, or damage to the fibers in ginning may change the mean or mode, but the major portion of fiber irregularity is accounted for by the differences on individual seeds.

REVIEW OF LITERATURE

Cook (2) described the inequalities in length of cotton fibers on a single seed and designated the shorter fibers as "substaple." Porter (7) studied differences in length of fibers from seeds at different positions on a single plant and found that mean lengths of fiber varied appreciably in different bolls, within locks, and even in the fiber combed to either side of the raphe on a single seed. Richmond and Fulton (8) studied fiber length in a commercial strain of Pima cotton and concluded that the individual seed contributed 98% of the variation measured. Their studies indicated that fiber from individual plants with wide differences in mean length, when composited, gave a fiber array little different from that of a uniform variety.

O'Kelly (6) studied the spinning quality of lint mixtures obtained from plots planted with seed of two varieties mechanically mixed before planting. He concluded that, ". . . the spinning efficiency of a variety was affected very little by the addition of a small percentage of lint of a variety with widely different fiber properties and still less or none when the fiber of the two varieties did not differ much." O'Kelly further stated that, "Seasonal variations, particularly in rainfall, can produce greater differences in spinning quality than will ordinarily be found between two varieties well adapted to and widely grown in a community."

In the processing field, Dunkerley (3, 4) conducted extensive research on fiber blending with Egyptian cottons and concluded that: "Cottons contribute their undiminished quota to the yarn strength of mixings proportional to the quantities present, however many components there may be to the mixing and whatever the proportions mixed." He found this rule to hold ". . . whether the staples mixed are long or short, fine or coarse, high grade or low grade, strong or weak." This finding, if given agronomic implication, can be of major importance to cotton breeders by placing uniformity of fiber properties in proper perspective.

MATERIALS AND METHODS

The present study was designed to compare the spinning performance of cotton from the growth of an individual (so-called uniform) variety with that of lint mixtures prepared by blending fiber from two varieties differing widely in one or more of the physical properties considered important in spinning; namely, length, strength, and fineness.

Fiber from 6 varieties (natural growth) was used in each of the 2 years of study. Spinning tests were made on fiber from each of the varieties separately and on 1:1 lint mixtures of all possible combinations of the 6 varieties. Thus, the spinning tests for each year comprised 6 straight varieties and 15 varietal blends. The 1:1 blends were prepared by thoroughly mixing the seed cotton and then ginning on a saw gin. The ratio of 1:1 in weight of lint was maintained in each blend by adjusting the amount of seed cotton included from each variety on the basis of its lint percentage.

The original spinning tests of all lots were made by the laboratory of the Cotton Division, A.M.S., College Station, Tex., on 5-pound samples. Remnant samples from the test lots were rechecked for spinning performance at the laboratory of the Section of Cotton and Other Fiber Crops, A.R.S., Knoxville, Tenn., on 1-pound samples. Small scale spinning tests are generally accepted as a satisfactory index of yarn strength, waste, neppiness, and yarn appearance but the term "spinning performance" should be construed within the limitations of the tests.

RESULTS

Fiber properties and spinning performance of straight varieties and varietal blends from the crop of 1950 are given in table 1. The six straight varieties used in 1950 represent a wide range of fiber properties: length, 0.94 to 1.42 inches; fineness, 393 to 549 mm.^{2}/mm.^{3}; and strength, 1.36 to 2.24 g. per grex as measured on the Stelometer at ⅛ inch gauge and designated as T_1. The range in these property values is well beyond any that normally would be

Table 1.—Fiber properties and manufacturing performance of six varieties and fifteen 1:1 varietal mixtures of cotton fiber. Crop of 1950.

Variety or Mixture	Fiber properties				Manufacturing performance			
	Length		Fineness arealometer (A)	Strength (T_1)	Yarn strength 22s	Waste picker and card	Neps per 100 sq. in.	Yarn appearance index
	U.H.M.	Mean						
Sealand	1.42	1.12	549	2.24	148	8.95	90	73
Coker 100 Staple	1.19	1.01	531	1.83	124	7.37	38	93
Hopi Acala	1.09	.93	399	2.00	115	10.12	27	100
Hibred	.94	.80	402	1.52	94	8.58	14	107
Mebane	1.03	.87	452	1.36	85	9.39	24	100
Rowden	1.06	.92	393	1.49	92	7.97	17	103
Sealand and Coker 100 Staple	1.29	1.05	533	1.90	131	8.29	70	83
Sealand and Hopi Acala	1.28	1.03	472	1.87	128	8.25	38	93
Sealand and Hibred	1.21	.91	479	1.91	121	8.55	38	93
Sealand and Mebane	1.28	1.00	501	1.96	110	8.86	48	90
Sealand and Rowden	1.27	1.03	460	1.90	117	7.56	34	93
Coker 100 Staple and Hopi Acala	1.18	1.01	453	1.67	115	8.46	27	100
Coker 100 Staple and Hibred	1.09	.91	473	1.66	108	9.07	24	97
Coker 100 Staple and Mebane	1.10	.89	464	1.57	102	8.09	27	97
Coker 100 Staple and Rowden	1.12	.96	457	1.65	111	7.65	21	100
Hopi Acala and Hibred	1.00	.80	409	1.86	101	8.95	11	113
Hopi Acala and Mebane	1.05	.89	428	1.62	93	9.15	20	103
Hopi Acala and Rowden	1.08	.91	399	1.56	98	8.58	11	107
Hibred and Mebane	.96	.81	420	1.38	90	8.98	17	103
Hibred and Rowden	.95	.80	391	1.49	92	8.01	12	110
Mebane and Rowden	1.04	.90	422	1.37	89	8.64	22	100

Table 2.—Fiber properties and manufacturing performance of six straight varieties of cotton and blends thereof, expressed as a percentage (gain or loss) of the blend over the mean of the component varieties. Crop of 1950.

Property or manufacturing performance	Deviation of blends from mean of component varieties						
	Sealand blends	Coker 100 Staple blends	Hopi Acala blends	Hibred blends	Mebane blends	Rowden blends	All blends average
	%	%	%	%	%	%	%
Upper half mean	2.4	0.9	0.9	−1.0	0.0	−0.9	0.4
Mean	−2.0	−1.0	−1.0	−4.5	−2.2	−2.1	−2.1
Fineness	−0.6	−1.9	0.0	0.0	−1.5	−0.9	−0.8
Fiber strength	−1.5	−5.1	−7.0	+0.6	−0.6	+3.2	−1.5
Yarn strength	−3.2	−2.6	−4.5	−1.9	−3.0	−1.9	−2.9
Waste	−5.9	1.5	−6.6	0.5	−2.9	−4.0	−2.9
Neps	−19.3	−5.6	−34.4	−25.9	−12.9	−28.6	−21.1
Yarn appearance	3.4	0.0	5.1	2.0	1.0	3.0	2.4

combined in manufacturing blends or that ordinarily would be found in a mongrelized agronomic variety. In manufacturing performance, the straight varieties ranged from 85 to 148 in strength of 22s yarn, from 7.37 to 10.12 in percent waste, from 14 to 90 in neps per 100 square inches of card web, and from 107 to 73 in yarn appearance index. Among the straight varieties, Sealand had an extremely high arealometer value and the yarn had an exceptionally high nep count. This neppy condition of Sealand was reflected in blends with this variety. Hopi Acala was obtained from a lot of mechanically harvested cotton and contained considerable foreign matter. This sample was classed as strict low middling and was the only straight variety sample classed lower than middling grade. Picker and card waste was high on the Hopi Acala sample.

One way of evaluating the manufacturing performance of blends is to compare actual performance with that expected from the calculated mean of the component varieties. For convenience in making this comparison, the differences have been calculated between the values for the blends and the means of the values for the component varieties. The data for the 1950 crop are presented in table 2. The deviations for each property are expressed in percentage gain or loss for the blend over the component varieties.

The spinning laboratory spun all samples under code numbers without knowledge of the identity of the individual lots. Their reports stated that the manufacturing performance of all samples (straight varieties and blends) was good, indicating no difficulty in processing any of the samples. The processing data, however, indicate some consistent trends that may or may not be significant. In all cases, (table 2) strength of 22s yarns of the blends was slightly less than the mean of the component varieties, averaging 2.9% lower. Four of the six blends were less wasty than the mean of the component varieties, all blends averaging 2.9% less waste. The blends had fewer neps, averaging 21.1% less than would be expected from the calculated means of the component varieties. The lower nep count is also reflected in the better than expected yarn appearance index of the blends.

The fiber properties from the varietal blends indicate that a 1:1 fiber mixture approximates the arithmetic average of the 2 component varieties very closely on all measured properties, with deviations averaging about 1%. There are no consistent trends in the fiber data to indicate

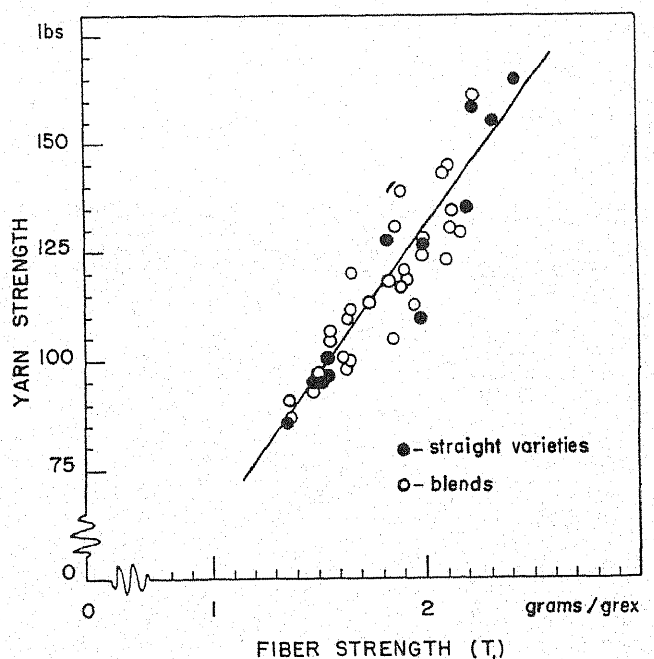

FIG. 1.—Relation of yarn strength to fiber strength (T_1).

that the blends behave differently from straight varieties or that the minor differences obtained in the measurements are other than sampling or instrument errors.

This study of the spinning performance of fiber from straight varieties and from varietal blends was repeated with cottons from the crop of 1951. The 6 straight varieties used in 1951 represented a range of fiber properties comparable to those from the 1950 crop. All straight varieties were classed as middling or above in grade except Stormproof. This variety was mechanically harvested and was classed as strict low middling.

Fiber properties and spinning performance of samples from the 1951 crop are given in table 3 and a comparison of fiber properties and manufacturing performance of the straight varieties and blends is given in table 4. As in 1950, the fiber properties and spinning performance of the varietal blends approximate very closely the arithmetic average of the component varieties. The average difference between the values for the blends and the means of the values for

Table 3.—Fiber properties and manufacturing performance of six varieties and fifteen 1:1 varietal mixtures of cotton fiber. Crop of 1951.

Variety or Mixture	Fiber properties				Manufacturing performance			
	Length		Fineness arealometer (A)	Strength (T_1)	Yarn strength 22s	Waste picker and card	Neps per 100 sq. in.	Yarn appearance index
	U.H.M.	Mean						
Sealand	1.34	.99	504	2.44	153	6.62	19	103
Acala 4-42	1.19	.99	416	2.23	131	5.05	3	113
Hopi Acala	1.13	.98	419	2.32	152	6.42	4	117
Stormproof	1.03	.82	464	1.57	102	13.00	4	103
Mebane	1.04	.91	405	1.55	91	6.28	4	120
Rowden	1.06	.89	349	1.98	110	7.89	1	117
Sealand and Acala 4-42	1.23	.99	441	2.08	142	6.59	15	100
Sealand and Hopi Acala	1.24	1.01	456	2.24	149	6.14	15	103
Sealand and Stormproof	1.21	.97	473	2.12	128	9.17	8	107
Sealand and Mebane	1.16	.93	444	2.09	119	6.55	14	100
Sealand and Rowden	1.16	.94	409	2.17	130	6.38	10	103
Acala 4-42 and Hopi Acala	1.17	1.00	419	2.12	141	6.45	4	113
Acala 4-42 and Stormproof	1.11	.90	429	1.84	115	9.66	10	103
Acala 4-42 and Mebane	1.09	.91	407	1.74	106	5.91	6	113
Acala 4-42 and Rowden	1.12	.93	386	1.99	122	6.87	3	113
Hopi Acala and Stormproof	1.12	.92	435	2.01	126	8.73	6	103
Hopi Acala and Mebane	1.09	.91	409	1.93	115	5.70	5	113
Hopi Acala and Rowden	1.11	.97	385	2.13	129	6.69	3	110
Stormproof and Mebane	1.00	.80	423	1.52	101	8.92	4	110
Stormproof and Rowden	1.03	.84	409	1.63	96	9.36	5	110
Mebane and Rowden	1.04	.88	382	1.64	97	7.68	2	113

Table 4.—Fiber properties and manufacturing performance of six straight varieties of cotton and blends thereof, expressed as a percentage (gain or loss) of the blend over the mean of the component varieties. Crop of 1951.

Property or manufacturing performance	Deviation of blends from mean of component varieties						
	Sealand mixes	Stormproof mixes	Hopi Acala mixes	Acala mixes	Mebane mixes	Rowden mixes	All mixes average
	%	%	%	%	%	%	%
Upper half mean	−0.9	0.0	1.8	−1.7	1.8	−1.8	−0.9
Mean	1.0	0.0	1.1	−1.0	−3.3	−1.1	−0.6
Fineness	−0.7	−1.8	−0.7	−1.4	−1.2	−0.5	−1.1
Fiber strength	−2.3	−1.1	−2.3	−7.1	−2.7	−4.5	−3.3
Yarn strength	−0.7	−1.7	−2.2	−1.6	−2.7	−2.5	−1.9
Waste	−2.9	−5.8	−5.1	8.4	−1.3	−3.6	−1.7
Neps	9.1	40.0	40.0	60.0	20.0	25.0	32.4
Yarn appearance	−5.5	−1.8	−3.6	−4.4	−5.2	−3.5	−4.0

the component varieties did not exceed 3.3% for any of the fiber properties measured.

As in 1950, there was a consistent trend for the yarn strength of the blends to be slightly lower than the average of the component varieties, and the picker and card waste of the blends was slightly less. Among the 1951 samples, the blends had slightly more neps than the average of the component varieties, but in no case was the yarn appearance index lower than 100 for the blends.

Residues of the raw cotton samples of the 1950 and 1951 crops were rechecked for spinning performance and yarn strength at the Knoxville Spinning Laboratory. There was no tendency in either the 1950 or 1951 samples for the blends to show spinning characteristics different from those of straight varieties. There was a small difference in the level of yarn strength on the same samples spun at the two laboratories. This difference in level was consistent for both 1950 and 1951 samples. There is a very high correlation, however, between the yarn strength values at the two laboratories; r being 0.98 and 0.99 for the 1950 and 1951 crops, respectively.

The techniques of blending and a knowledge of the behavior of specific blends is important in textile manufacturing, but fiber irregularities that occur as a result of genetic variability and growth conditions are not so readily controlled. Natural blends, as would result from genetic variability in the seed stocks of a variety, could properly be penalized only if their spinning performance was less satis-

factory than would normally be predicted from their fiber properties.

Landstreet (5) states that fiber strength accounts for approximately 88% of yarn strength when yarns are spun at optimum twist. Brown (1) found a close correlation ($r = 0.91$) between yarn strength and fiber strength measured at 4 mm. gauge length. In fact, 15 of the 105 samples used by Brown in developing his data, were coded blends from the 1951 crop of this experiment. In figure 1, yarn strength has been plotted against fiber strength (T_1) for the blends and straight varieties of the 1950 and 1951 crops. The yarn strength values are those obtained at the Knoxville Spinning Laboratory. The correlation coefficient for the combined data is 0.91. It is apparent from the graph that the yarn strengths of the blended samples and of the straight varieties are equally related to fiber strength.

DISCUSSION

On the basis of these results there would be no advantage to a farmer or ginner in deliberately mixing long fiber and short fiber cottons in the hope of obtaining a higher market price for the mixture. Rather, the mixture would have less market value than that of the two varieties if sold separately. For example, a 1¼ inch middling cotton might have a value of 1,200 points—on the basis price for 15/16 inch middling. But if 1¼ inch and 15/16 inch cottons are blended in a 1:1 mixture, the blend would have a staple length of approximately 1-3/32 inches and would be worth about 315 points—on basis price; considerably less than the average of 600 points—on that might be obtained if the two cottons were sold separately.

In the textile mills, blending is a customary and necessary practice used as a means to stabilize the product of the mill from day to day and even from year to year. By careful selection of the bales incorporated in the blend, a balanced mix is maintained and a consistent product is produced. Emphasis in the mill is not upon fiber irregularities per se among the individual fibers but upon the consistent level of the properties of the mass of raw fibers being processed through the mill.

The data presented here indicate that mixtures of lint from varieties having widely different fiber properties have adequate uniformity in-so-far as spinning performance and yarn strength are concerned. As shown in tables 1 and 3, the blends spin no differently than straight varieties and at levels of yarn strength that would be expected from their measured fiber properties.

If fiber irregularity, such as has been introduced into the blended samples tested in this experiment, has no important effect on the final spinning performance of the composited mass of fibers, general recognition of this fact may relax present standards for uniformity in cotton varieties; standards that are now considered necessary. Line breeding or selfing may result in an approach to genetic uniformity, but also it may result in actual deterioration in variety value if continued beyond the minimum requirements for stability (10). Stephens (9) states, "The successful variety is a population of plants which retains sufficient genetic variability to ensure adaptability under different environmental and seasonal conditions—a variable population whose *mean* performance approaches the breeder's ideal."

Many cotton breeders have limited the variability in their varieties to that maintained by carrying a few closely related strains in their breeding blocks and combining these strains for varietal release. If "adequate uniformity" is obtained in blends such as have been described, it follows that considerable genetic variability may be allowable in cotton varieties so long as a desirable level in fiber properties is maintained. The use of advanced generation hybrids or synthetic varieties for commercial cotton production will create no insurmountable problems in spinning.

SUMMARY

Spinning tests were made on cotton lint from individual varieties and on lint mixtures prepared by blending fiber in the ratio of 1:1 by weight from varieties differing widely in one or more physical properties. Samples of fiber from the varietal blends approximated the arithmetic average of the two component varieties very closely in length, strength, and fineness, and in yarn strength. Within the scope of this experiment, there was no tendency for the blends to show spinning characteristics different from those of straight varieties. Correlation data indicate that the yarn strength of the blended samples and of the straight varieties are equally related to fiber strength.

Apparently, fiber irregularities such as were introduced in this experiment by blending unlike varieties, had no important effect on spinning performance. Logically, fiber irregularities of a similar nature, that may be introduced by a breeder in hybrid or synthetic varieties, can have little effect on the value of the fiber except as such irregularities are reflected in the properties of the mass fiber.

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Evaluation of Bulk Hybrid Tests for Predicting Performance of Pure Line Selections in Hard Red Winter Wheat[1]

Wayne L. Fowler and E. G. Heyne[2]

HYBRIDIZATION, followed by selection of desirable segregates, is one of the important methods of small grain improvement. Efficiency in breeding self-pollinated crops can be increased if the value of crosses or selections is determined during early generations. This paper reports the results of an experiment designed to determine the value of early generation bulk hybrid tests to predict the performance of pure line selections in hard red winter wheat.

LITERATURE REVIEW

Harlan *et al.* (5) carried 379 bulked barley crosses as unselected populations for 7 generations and found that a preselection yield classification of the crosses agreed with the relative yield of selections made in the F_8 generation. It was concluded that the low yielding group of crosses, constituted by the poorer types, could just as well have been discarded before selection. Atkins (1), however, found that selection based on several plant characteristics contributing to yield was not effective in isolating high yielding lines from bulked barley crosses grown in Iowa. Immer (7) suggested that the average yield of bulk F_2 and F_3 generation barley crosses would be valuable for detecting the better crosses of a group. Grafius *et al.* (4) reported most of the variance in yield of bulked F_2 barley progenies to be nonheritable. The more homozygous F_3 generation showed increased heritability of yield.

Harrington (6) found that bulk F_2, supplemented by F_3, generation yield results accurately evaluated six wheat crosses when selected lines were tested in F_6, F_7, and F_8 generations.

Atkins and Murphy (2) classified 10 oat crosses as high or low yielding on the basis of bulk F_2 through F_6 generation tests and found that as many high yielding F_7 segregates came from the crosses classified as low yielding as from the high yielding group. Test weight was found to be reliably predicted in this study.

Kalton (8) found maturity, plant height, and lodging to be relatively constant in the bulk F_2, F_3, and F_4 generations of 25 soybean crosses, but yield differences were inconsistent from generation to generation. Mahmud and Kramer (9) reported that the effect of environment was great enough to reduce yield heritability estimates on early generation tests of soybeans to negligible values, while those for maturity and plant height remained high. Tests of bulk populations of F_2 through F_5 generations of soybean crosses were not reliable in predicting yield or maturity date of selections, but lodging and height evaluations were consistently indicative of the performance of these same selections, according to Weiss (11) and Weiss *et al.* (12).

MATERIALS AND METHODS

Ten varieties of winter wheat, representing a wide range of types, were intercrossed in all possible combinations in 1942. The parental varieties were: Blackhull, CI 6251; Cheyenne, CI 8885; Chiefkan, CI 11754; Comanche, CI 11673; Early Blackhull–Tenmarq, Ks 2757; Marquillo–Oro, CI 11979; Nebred, CI 10094; Pawnee, CI 11669; RedChief, CI 12109; and Tenmarq, CI 6936. All are, or have been, commercially important varieties in the hard red winter wheat area except Ks 2757 and CI 11979. The 45 crosses were grown in bulk from the F_2 through the F_5 generation. The 45 bulked crosses and their 10 parents were grown in 1946, 1947, and 1948. The F_3 generation was grown all 3 years, the F_4 in 1947 and 1948, and the F_5 in 1948. A randomized complete block design, with single- or 2-row, 8-foot plots replicated 5 or 10 times was used for these early generation tests. Seed from the parents and F_5 bulks was space planted in 1949; 10 plants were selected at random from each cross and 5 from each parent. Seed of these individual plants was increased in 1950 and 7 or 8 pure line selections from each cross and 2 from each parent were grown in 2-row and 4-row plots 8 feet long in a 7 by 7 by 7 cubic lattice design in 1951 and 1952.

Yield in grams per 8-foot row, plant height in inches, date in May on which the half-bloom stage was reached, and test weight in pounds per bushel were recorded for all kinds[3] during this study. All tests were conducted at Manhattan, Kans.

The statistical methods as outlined by Cochran and Cox (3), Snedecor (10), and Yates and Cochran (13) were used throughout the study. Combined analyses of variances, using all the available data for any one generation, were performed for each characteristic studied. Each early generation kind was characterized by combining and analyzing results of F_3, F_4, and F_5 generations grown in 1946, 1947, and 1948, respectively. Product-moment correlation coefficients for each characteristic were calculated between logical combinations of generations and years. Results of the cubic lattice trials were analyzed by the punched-card method at the Statistical Laboratory, Kansas State College.

EXPERIMENTAL RESULTS

Table 1 summarizes most of the data obtained during the course of the study. Variety averages are given to characterize each parent. The performances of the bulks are based on 3 successive generation-year results of tests involving the 9 bulked crosses with 1 parent in common. Such an average is the logical one to use to characterize early generation bulked cross performance, since results of successive generations grown in consecutive years would be available in a practical early generation test program. Selection averages cover the 2-year performance of the 64 or 65 pure lines having a common parent. Direct comparisons between varieties, bulks, and selections should not be made since different years are involved.

Yield

A combined analysis of F_3 (1946), F_4 (1947), and F_5 (1948) generation yields showed no significant difference among the 55 kinds. Average yields ranged from 206.4 to 156.2 g. with 8.34 as the standard error of a kind mean. However, there were highly significant differences in yield between kinds in all generations and years. When kinds were ranked according to yield, a striking inconsistency in relative yield from generation to generation and year to year was apparent.

Correlations, shown in table 2, were significant in only one out of 11 individual comparisons. This highly significant yield correlation between F_3 and F_4 generations, when year to year variation was eliminated by growing them both in 1947, might indicate a certain degree of relationship; however, the correlation between these same generations

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[3] "Kinds" is used throughout the paper to include the 45 bulked crosses and the 10 parents.

Table 1.—Performance, at Manhattan, Kans., of 10 winter wheat varieties, of the bulked progeny of each variety crossed with each of the remaining 9, and of the random selections (total number indicated) from each bulk population.

Parental varieties	Average yield, Bu./A.			Average plant height, Ins.			Average date of flowering, May 1 = 1			Average test weight, Lbs./Bu.			No. sels.
	Variety, 1935–46	Bulks, F_3–F_5, 1946–48	Selections, 1951–52	Variety, 1946–48	Bulks, F_3–F_5, 1946–48	Selections, 1951–52	Variety, 1946–48	Bulks, F_3–F_5, 1946–48	Selections, 1951–52	Variety, 1946–48	Bulks, F_3–F_5, 1946–48	Selections, 1951–52	
Blackhull	25.1	31.3	35.1	42.9	41.1	40.9	22.7	15.3	26.7	58.2	58.8	59.2	64
Cheyenne	26.1	29.9	36.1	40.2	40.9	40.3	24.6	16.5	27.5	56.5	57.9	58.7	64
Chiefkan	27.5	31.2	35.2	42.2	41.4	41.4	22.4	15.6	26.8	58.6	58.4	59.4	65
Comanche	30.4	31.6	36.9	39.4	40.2	40.6	21.1	13.9	26.7	56.8	58.2	58.7	65
Early Blackhull–Tenmarq	34.1	31.5	36.3	38.0	39.5	39.9	15.8	11.6	24.4	58.4	59.2	59.2	64
Marquillo–Oro	30.8	31.9	37.0	42.1	40.4	40.3	26.4	15.9	27.5	55.3	57.7	58.3	65
Nebred	26.2	30.7	35.4	39.4	40.4	40.2	24.0	15.8	27.7	58.5	58.2	58.7	65
Pawnee	33.8	30.1	35.4	38.0	39.5	39.7	20.1	14.6	26.6	57.4	58.1	58.6	65
RedChief	25.9	30.6	34.9	41.4	40.8	41.4	21.0	15.2	26.9	60.4	59.3	60.1	65
Tenmarq	27.3	30.3	36.0	40.9	41.0	40.7	22.9	15.4	27.1	56.0	57.9	58.4	64

Table 2.—Product-moment correlation coefficients of early generation bulk data, 1946–48. Degrees of freedom = 53.

Generation	Yield	Plant height	Date of flowering	Test weight
	r =	r =	r =	r =
With generation to generation variation eliminated:				
F_3 (1946) vs. F_3 (1947)	0.00	0.85**	0.96**	0.84**
F_3 (1947) vs. F_3 (1948)	0.01	0.84**	0.95**	0.69**
F_3 (1946) vs. F_3 (1948)	0.15	0.91**	0.98**	0.48**
Average, F_3 (1946) to F_3 (1948)	0.05	0.87**	——	——
F_4 (1947) vs. F_4 (1948)	0.14	0.60**	0.91**	0.66**
With year to year variation eliminated:				
F_3 (1947) vs. F_4 (1947)	0.40**	0.96**	0.93**	0.70**
F_3 (1948) vs. F_4 (1948)	−0.02	0.88**	0.97**	0.88**
F_4 (1948) vs. F_5 (1948)	0.23	0.83**	0.95**	0.85**
F_3 (1948) vs. F_5 (1948)	0.13	0.94**	0.95**	0.93**
Involving successive generation-years:				
F_3 (1946) vs. F_4 (1947)	−0.11	0.71**	0.94**	0.54**
F_4 (1947) vs. F_5 (1948)	−0.09	0.68**	0.90**	0.70**
F_3 (1946) vs. F_5 (1948)	0.12	0.75**	0.93**	0.65**
Average, F_3 (1946) to F_5 (1948)	−0.03	0.73**	0.92**	0.63**

** Significant at the 1% level.

did not approach significance when they were both grown in 1948. The three correlations involving successive generation-years (table 2) were nonsignificant. Yields of bulks in any year or generation were not indicative of yields in other years or generations. Neither was there any significant association of different generations of the same bulk grown the same year. It was not possible to designate any kind or group of kinds as high or low yielding on the basis of these early generation tests.

Highly significant differences in yield existed among the parents and pure line selections in each of both years they were studied (1951 and 1952). The best available estimate of the yield performance of selections from each cross or variety is the mean yield of all selections from each kind averaged over the 2 years they were grown. The average yield of all selections from each kind ranged from 198.3 to 160.4 g. per 8-foot row. The selections from Marquillo–Oro had the highest average yield; those from Pawnee × Early Blackhull–Tenmarq, the lowest. These had not been identified as high or low yielding kinds during early generation tests.

The correlation between the yield of the early generation kinds and that of selections from each kind was 0.28 (table 3), a significant correlation coefficient. However, the analysis of the early generation yield results showed no significant difference among the 55 kinds when averaged over 3 successive generation-years so this low, but statistically significant, correlation coefficient probably has little meaning. It was concluded that the yield of the early generation bulked crosses was of no value for predicting the yield of the pure line selections.

Plant Height

Highly significant plant height differences among kinds were found to exist in all early generation tests. A ranking

of kinds according to plant height showed a general agreement from generation to generation and from year to year. The plant height correlations given in table 2 are all highly significant and indicate that height determinations made during any one generation or year were reliable indicators of the relative plant height of the same kinds grown in other generations or years. The mean plant height of individual kinds tested in 1946–48 varied from 43.1 to 37.6 inches, with 0.40 as the standard error of a kind mean. A combined analysis showed a highly significant difference between average heights of early generation kinds.

Significant differences in plant height were found to exist between the pure line selections and parents tested in 1951 and 1952. As the variation between crosses was greater than, or equal to, variation within crosses and in only one case was there a significant difference between selections from a variety, the post-selection performance of a cross or variety could be represented by the average performance of all selections from a kind. The average height of all selections tested in 1951–52 from each of the 45 bulks and 10 parents ranged from 43.0 to 38.1 inches. The selections from the Chiefkan parent averaged tallest; those from Pawnee shortest. Chiefkan had been among the tallest kinds in all early generation tests; Pawnee had been among the shortest.

The average successive early generation kind plant height was correlated with the 2-year average of mean plant heights of all selections from each kind. The correlation coefficient was calculated to be 0.73 (table 3), a highly significant value. This indicates that random selections from each kind tended to have an average plant height similar, relatively, to that of the kind from which they were selected.

Date of Flowering

There was a highly significant difference among kinds in all early generation tests. A ranking of kinds according to maturity showed a close relative agreement from generation to generation and from year to year. Product-moment date of flowering correlation coefficients given in table 2 are all highly significant. There is apparently little year to year variation in relative maturity. Early generation kinds could have been grouped according to date of flowering in any one test and this grouping would have reliably indicated the relative maturity to be expected from the same entries in any succeeding generation and/or year.

A combined analysis of flowering date of F_3 (1946), F_4 (1947), and F_5 (1948) generation bulks and parents, undertaken to determine the average early generation performance, showed a highly significant difference among kinds. Mean dates of flowering of the 55 kinds tested in 1946–48 ranged from 20.4 to 9.7 with 0.59 day as the standard error of a kind mean.

Analysis of the 1951 and 1952 cubic lattice trials showed significant differences among the pure line selections and parents in each of both years. The best available evaluation of the post-selection flowering date of any of the crosses or varieties was a 2-year average of the mean date of flowering of all selections from each kind. These averages ranged from 31.5 to 20.6. The selections from Marquillo–Oro, a late kind in early generation tests, averaged latest of any of the 55 kinds; the selections from Early Blackhull–Tenmarq, the earliest kind in early generation tests, averaged earliest over the 2 years.

The product-moment correlation coefficient between kind dates of flowering averaged over 3 successive early generation-years and 2-year average of mean dates of flowering of all selections from each kind was 0.83 (table 3), a highly significant value. The relative average date of flowering of random selections from each kind was similar to the relative date of flowering of these 55 bulked kinds during their early generations. Maturity is a characteristic that apparently was accurately predicted by early generation tests.

Test Weight

Statistical tests of the test weight of grain from the 55 early generation kinds were not so powerful as those for the other characteristics studied because only one observation was recorded for 1946 and 1947 tests and two for 1948. The single value was used as the best available estimate of test weight for each 1946 and 1947 test. 1948 data were subjected to an analysis of variance, with only one degree of freedom for replications.

Analysis showed highly significant differences among kinds in all 1948 tests. A ranking of kinds shows a fair agreement in relative kind test weight from generation to generation and from year to year. In general the kinds having the lowest test weights tended to be the most consistent. The correlation coefficients given in table 2 are variable but highly significant. When the year to year influences are removed, the numerical value of the correlations is increased. It seems that the effect of years operates to reduce inter-generation correlations of test weight. Although there is a certain amount of consistency from generation to generation and year to year, it appears that determinations made on one generation grown in any one year might prove disappointing if used to predict the performance of a kind in some later generation or year.

Single determinations of test weight in 1946 and 1947 reduce the weight of conclusions that can be drawn from an analysis of successive F_3, F_4, and F_5 kind test weights. Arrayed test weights ranged from 60.7 to 55.7 pounds per bushel with 0.36 as the standard error of a kind mean.

Significant differences among test weights of randomly selected lines were observed in 1951 and 1952. The 2-year average test weight during 1951–52 of all selections from a cross or variety, used as a measure of the post-selection performance, ranged from 61.6 to 56.2 pounds per bushel. Selections from the RedChief parent had the highest test weight of selections from any kind; RedChief was determined statistically, to be the heaviest kind during early generation tests. Selections showing the lowest average test weight were those from the Marquillo–Oro parent, the lightest kind in early generation tests.

A highly significant correlation coefficient of 0.83 (table 3) was obtained between the average test weight of grain from the 55 early generation kinds and the 2-year average of mean test weights recorded for all selections from each kind. This indicates that the relative test weight of kinds averaged over 3 successive generation-years was similar to the relative mean test weight of random selections from each kind when averaged over the two-year period.

Predictions Based on Parental Characteristics

The average performance of the 10 parents was compared with the performance of the bulked crosses and pure line selections by correlation. Table 3 shows the correlation coefficients obtained, plus those previously reported for

Table 3.—Product-moment correlation coefficients involving parents, bulked crosses, and selections.

	D.F.	Yield	Plant height	Date of flowering	Test weight
		r =	r =	r =	r =
Parents vs. bulked crosses	8	0.26	0.85**	0.91**	0.85**
Parents vs. selections	8	0.48	0.76*	0.92**	0.91**
Kinds vs. selections	53	0.28*	0.73**	0.83**	0.83**

* Significant at the 5% level.
** Significant at the 1% level.

comparisons among kinds and selections. Significant or highly significant correlation coefficients among parents and selections were obtained for plant height, date of flowering, and test weight. A non-significant correlation coefficient resulted in the case of yield. Except for yield, the performance of a variety was reliable in predicting the performance, for the characteristics studied, of selections involving that variety as a parent. An outstanding example of this is the case of test weight (table 1). Marquillo-Oro had the lowest test weight of the parental varieties; bulks and selections involving this variety as a common parent were lowest in their respective groups. Similarly, bulks and selections involving RedChief, the heaviest parent, were the heaviest in their groups.

Fisher's z-test was applied to determine whether the numerically higher values for parent-selection correlation coefficients differed from those for bulk-selection correlation coefficients. In no case did the difference in coefficients approach significance; therefore, the parents could not be considered more reliable as predictors of selection performance than the bulk hybrids.

DISCUSSION AND CONCLUSIONS

Generation to generation and year to year inconsistencies in relative yield were so great that it was impossible to classify any kind, or group of kinds, as high or low yielding. Such inconsistencies were due to the interaction of many factors, both environmental and genetic, which operate directly and indirectly to influence yield response. Since preselection yield classification of the 45 bulk hybrids and 10 parental varieties could not be accomplished, it was concluded from this study that the early generation bulk hybrid tests were of no value in predicting the yield from selections from the 55 kinds. Parental performance was likewise of no value for predicting yield performance of the selections studied. From the results of this study the probability of obtaining a high yielding line by selection was apparently equal, no matter from which cross the selection was made.

Techniques used for determining yield in cereals apparently are not refined enough to detect real yield differences if they are only in the magnitude of about 10%. The 10 parents used in this study were, at one time or another, recognized for their yield potential in Kansas. Blackhull was highest in measured yield at Manhattan at least once during the period 1935–1954 but for the 12 years, 1935–1946, it had the lowest average yield of the parents involved (table 1). In the cross-combinations studied, perhaps the factors for yield were uniformly distributed and therefore no yield difference could be observed in the bulk generations.

There are many factors of the environment, separate from the inherent yielding ability, that affect actual yield. An example would be the presence of soil borne diseases in irregular distribution in the test area. In the 1954 test area at Manhattan there were areas only 3 feet in diameter that showed drought damage; the effects of soil borne mosaic were evident in areas equally as small. As long as the environment, such as encountered in Kansas, varies so greatly from season to season and even within the same season and location the presently used techniques for measurement of yield will give variable results. Only under rigid control of the environment will the inherent yield potential be measured accurately for any specific set of conditions. Therefore, if any real yield differences occurred through recombinations (transgressive segregation) the detection of such recombinants in bulk hybrids probably would not be observed.

Significant correlation coefficients indicated that preselection classification of the 55 kinds was possible according to plant height, date of flowering, and test weight. A single test was sufficient to determine early generation performance but a better evaluation would be the average performance of the bulked crosses or parents when grown in successive years. Such an average, covering a random sample of years, takes into account any year by kind interaction that may be present.

Within the limits of this experiment it was shown that preselection determinations made on early generation bulk crosses reliably predict the relative plant height, maturity, or test weight of selections from those crosses. However, parental performance gave as reliable a preselection classification as that based on bulked crosses. The probability of obtaining segregates desirable in any of these three characteristics could have been increased either by studying the parents, and crossing only those showing the desirable attribute, or by discarding the undesirable bulks according to early generation performance.

Since parental performance was found to be equal to bulked cross performance in predicting plant height, date of flowering, and test weight, the use of bulked crosses to predict selection performance would seem to have no merit. Careful choice of parents to be used for making a relatively few crosses would have been more economical than making many crosses, some of which were to be discarded on the basis of their bulk performance. Indications are that selection during segregating generations should emphasize characteristics other than yield; it is likely that satisfactory yield will be manifest by many of the remaining segregates after selection for desirable observable and measurable characteristics has been accomplished. On the basis of this study in hard red winter wheat, it is suggested that the

analysis of many bulked crosses in early generations is not so economical in securing desirable segregates as other more commonly used plant breeding methods.

SUMMARY

Early generation tests of 45 bulked hard red winter wheat crosses and their 10 parents were conducted in 1946, 1947, and 1948 at Manhattan, Kans. Seven or 8 selections made at random from each space planted F_5 bulk hybrid were tested, along with 2 random selections from each parent, in 7 by 7 by 7 cubic lattice designs in 1951 and 1952. Results of the early generation trials were compared with those of selection tests to determine whether or not the early generation tests had indicated the performance that might be expected from selections from each cross.

It was not possible to classify the early generation crosses according to yield in this study probably due to high year to year variation in relative yield or inadequate technique for measuring yield. In the absence of a reliable preselection classification there was no basis for attempting to predict yield of the selections. Parental performance was also of no value in predicting yield of selections. Classification of the bulked crosses according to plant height, maturity, or test weight seemed to be reliable and consistent; apparently these preselection classifications accurately predicted the plant height, maturity, or test weight that might be expected in selections. Parental performance was shown to be just as reliable for predictive purposes as bulk hybrid performance.

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Persistence of Timothy As Determined By Physiological Response to Different Management Systems[1]

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FACTORS such as soil fertility and stage of harvest are recognized as having varying influences on the yield, quality, and longevity of different species of forage plants. Information is needed as to the specific effect and possible inter-relationships of management factors on forage plants. The objective of the experiments reported in this paper was to determine the effect of various fertilizer treatments on nitrogen and carbohydrate food reserves in timothy corms and roots when harvested at various stage of maturity. The effect of these treatments under field plot conditions on yield per acre of forage and protein is presented.

REVIEW OF LITERATURE

Literature related to food reserves in plants is extensive. Information pertaining to timothy will only be considered in this review.

Waters (11) observed that persistence of timothy stands could be enhanced by allowing plants to mature, thus promoting development of "bulbs" for propagation at the base of old timothy plants. In contrast, Wiggans (12) advanced the premise that early cuttings were beneficial in maintaining timothy stands, since weed competition would be eliminated; and he maintained that allowing plants to mature seed resulted in reduced plant vigor. Throwbridge *et al.* (9) found the greatest number of "bulbs" present when timothy was cut just out of bloom. Further evidence indicated that material stored in the timothy "bulb" was largely nitrogenous matter and nitrogen-free-extract. Sprague and Hawkins (8) noted that the protein content of timothy could be increased by application of soluble nitrogenous fertilizers 2 to 3 weeks prior to harvest. A practical method of improving storage reserves in timothy corms is thus implied.

PROCEDURES

Terminology used herein regarding the timothy plant is according to recommendations by Evans (3) with the exception that corm will be substituted for haplacorm. The term, reserve, shall be used to include nitrogen compounds and carbohydrates stored and utilized by a plant for maintenance and future growth.

A preliminary phase of the investigation involved an exploratory greenhouse study during 1940. The continuous flow method of Shive and Stahl (4) was utilized with 3 levels of nitrogen consisting of 14 ppm. (changed to 21 ppm. when nitrogen deficiency was evident), 126 ppm. and 315 ppm. Partial volume molar concentrations of K_2SO_4, KH_2PO_4 and $MgSO_4$ were constant at 0.001125. Minor elements added were Fe at 1 ppm. and B, Zn,

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[3] Anderson, J. C. A study of carbohydrate-nitrogen relationships in timothy plant tops. Thesis, Rutgers Univ. 1940.

Table 1.—Average dry weight in grams of quadruplicate samples of timothy plant fractions harvested per square foot, 1940 and 1941.

Treatment	Leaves		Stems and heads		Corms		Roots		Total plants	
	1940	1941	1940	1941	1940	1941	1940	1941	1940	1941
	Harvested early heading, June									
Check	11.0	10.1	14.7	12.2	8.8	7.1	12.0	9.8	46.5	39.2
Check+N at early heading in 1940 only*	——	11.0	——	11.4	——	7.0	——	11.3	——	40.7
400 lbs. A 5-10-5†	23.2	17.1	38.4	14.7	22.4	8.4	11.6	14.0	95.6	54.2
400 lbs. A 5-10-5+N at early heading	——	21.9	——	20.3	——	17.4	——	11.5	——	71.1
	Harvested beginning bloom, July									
Check	10.0	9.4	24.4	15.7	15.2	15.7	7.2	7.0	56.8	47.8
Check+N at early heading	18.4	16.3	67.6	43.4	28.0	22.3	8.0	7.7	122.0	89.7
400 lbs. A 5-10-5	29.2	28.4	101.6	78.3	32.4	24.6	7.6	6.4	170.8	137.7
400 lbs. A 5-10-5+ N at early heading	39.4	42.6	109.3	113.7	38.5	34.4	10.0	8.4	197.2	199.1
	Aftermath following harvest at beginning bloom, September									
Check	——	——	5.1	3.8	16.2	13.8	4.9	3.5	26.2	21.1
Check+N at early heading	——	——	30.5	5.8	22.2	20.6	7.4	3.8	60.1	30.2
400 lbs. A 5-10-5	——	——	7.2	13.6	27.8	26.2	5.8	4.5	40.8	44.3
400 lbs. A 5-10-5+N at early heading	——	——	36.3	23.2	38.0	32.6	7.3	5.9	81.6	61.7

* Nitrate of soda used to supply 36 lbs. N per acre.
† Complete fertilizer applied in spring.

and Mn at 0.25 ppm. Calcium was held constant using $CaCl_2$ and the pH was held constant at 5 using 0.5*N* NaOH to adjust outgoing solutions.

A field low in fertility consisting of a 1939 seeding of timothy was used for experimentation in 1940 and 1941. The soil was a Dutchess loam with a pH of 6.2. Treatments consisted of a check plot and a fertilized plot which received 400 pounds per acre of a 5–10–5 fertilizer applied annually in the spring. To determine effects of nitrogen stimulation, one-half of each plot was fertilized at early heading with nitrate of soda to supply 36 pounds of nitrogen per acre. Samples from 1-foot quadrants in quadruplicate were taken from each plot at early heading, beginning bloom and aftermath for plant fractionation into roots, corms, leaves, stems, and heads. Root penetration and distribution were studied at beginning bloom. Samples of roots and corms were taken according to methods by Sprague (7) with equipment by Blaser (2).

A more detailed study was initiated in 1940 with a seeding of timothy on a Dutchess loam of low fertility. Treatments on 10 by 20 foot plots in triplicate consisted of a check, 400 pounds per acre of 5–10–5, 400 pounds per acre of 5–10–5 plus 36 pounds

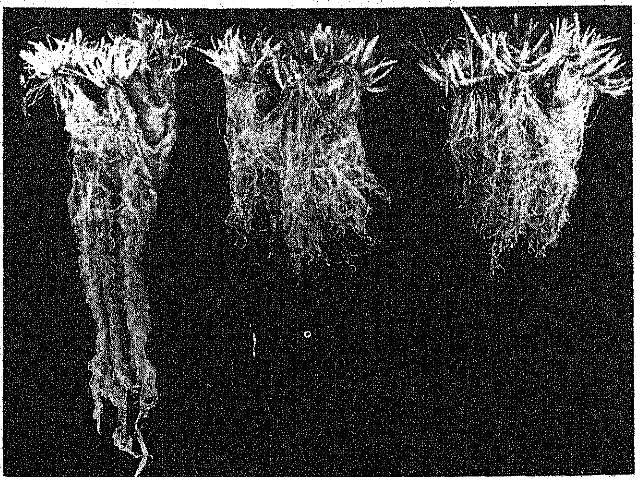

FIG. 1.—Character of root growth of timothy grown in nutrient culture under nitrogen levels of 21 ppm. (left), 126 ppm. (center) and 315 ppm.

of nitrogen from nitrate of soda in the spring, 1,200 pounds per acre of 5–10–5, and 400 pounds per acre of 5–10–5 plus 36 pounds nitrogen from nitrate of soda at early heading. Timothy was harvested from 1941 through 1944 at early heading, beginning bloom, and late bloom for forage yield. Protein yields were determined for 1941 and 1942.

Data on plant species, yield, and food reserves in corms were determined for each fertilizer treatment according to time of harvest during 1941. Botanical composition was determined by the inclined quadrat method as given by Tinney, Aamodt, and Ahlgren (10). Dry soil conditions during 1941 made the use of the instrument by Blaser (2) unsatisfactory. As a substitute, removal of 6 by 6 inch blocks with a spade was used to determine root weights.

Reducing sugars were determined from a 200-mg. sample of plant tissue hydrolyzed with 1:20 HCl for 3 hours under a reflux condenser. Reducing power of the filtrate was determined according to the method described by Wildman and Hansen (13).

Nitrogen of forage samples was determined by the standard Kjeldahl method (1). Nitrogen in plant fractions was determined by micro-Kjeldahl according to methods of Snell and Snell (6).

RESULTS AND DISCUSSION

Greenhouse Study

Data from the greenhouse study have not been included, since results were comparable to those of the field study. Worthy of special note, however, was the influence of nitrogen levels on the root development of timothy. As indicated in figure 1, high and medium nitrogen levels in the substrate (315 and 126 ppm., respectively) developed a short, heavy textured and succulent root system; while low nitrogen (21 ppm.) resulted in an extensive, fine textured, and fibrous root system.

Field Study

As shown in table 1, root weight was somewhat variable at early heading and beginning bloom. The effects of harvesting at beginning bloom, however, were reflected in decreased root weight at the time of aftermath harvest. During field sampling of roots, it was evident that growth

Table 2.—Fresh weight in grams of timothy roots per square foot of surface, per inch layer, under various soil treatments, July 3, 1940 and 1941.

Soil layer	Fertilizer treatment							
	Check		Check and nitrate in June		400 lbs./A 5-10-5 in spring		400 lbs./A 5-10-5 in spring and nitrate in June	
	1940	1941	1940	1941	1940	1941	1940	1941
0–2 inch*	43.6	41.6	65.6	48.8	89.6	73.6	106.6	87.2
2–3	11.6	13.9	15.1	19.6	16.3	21.1	19.7	19.4
3–4	8.6	10.8	11.8	13.9	12.2	12.6	13.8	11.5
4–5	5.1	6.6	5.8	3.8	6.2	6.6	5.4	6.2
5–6	5.8	5.5	4.8	5.1	6.9	3.1	4.3	5.9
6–7	3.9	2.8	2.0	2.2	3.0	2.5	1.7	3.0
7–8	1.9	1.3	1.3	1.1	1.1	0.9	1.2	1.0
8–9	1.3	0.9	0.6	0.7	0.8	0.6	1.0	0.3
9–10	0.6	0.6	0.3	0.0	0.3	0.0	0.2	0.0
Total root weight below 2 inches	38.8	42.4	41.7	46.4	46.8	47.4	47.3	47.3
Percent below 2 inches	47.1	50.5	38.9	48.7	34.3	39.2	30.7	35.1

* 0–2 inch weights largely made up of corms.

Table 3.—Nitrogen and carbohydrates in timothy corms harvested per square foot under different treatments at various times during the 1940 and 1949 growing seasons, average of quadruplicate samples.

Treatment	Dry weight		Nitrogen		Carbohydrates	
	1940	1941	1940	1941	1940	1941
	g.	g.	%	%	%	%
	Sampled at early heading, June					
Check	8.80	7.12	0.55	0.95	45.31	48.91
Check+N at early heading in 1940 only*	——	6.96	——	1.30	——	48.00
400 lbs./A 5-10-5†	22.40	9.44	1.07	1.27	38.26	47.34
400 lbs./A 5-10-5+N at early heading	——	17.36	——	1.21	——	44.22
	Sampled at beginning bloom, July					
Check	15.20	15.68	0.51	0.80	39.54	38.87
Check+N at early heading	28.00	22.32	1.27	1.15	35.18	34.71
400 lbs./A 5-10-5	32.40	24.56	0.57	0.82	33.61	36.64
400 lbs./A 5-10-5+N at early heading	38.50	33.36	1.19	1.09	41.32	43.30
	Sampled during September‡					
Check	16.16	13.84	0.88	1.29	40.63	47.21
Check+N at early heading	22.16	20.64	1.64	1.66	37.42	44.66
400 lbs./A 5-10-5	27.84	26.16	0.81	1.40	36.82	53.84
400 lbs./A 5-10-5+N at early heading	38.00	32.64	1.33	1.56	38.71	48.42

* Nitrate of soda used to supply 36 lbs. N per acre.
† Complete fertilizer applied in spring.
‡ Samples from area harvested at beginning bloom.

varied with the different treatments. Roots of timothy plants in check plots were more extensive, fibrous, and penetrated to greater depths than in fertilized plots. This is further substantiated in table 2 and is in agreement with the results from the greenhouse study. Differences of this type in root development might have important bearing on the ability of plants to withstand dry periods. In addition there is suggested the probable advantage of deeper placement of fertilizer.

Since the primary objective of this investigation was the relation of stored reserves to persistence, the chemical studies were confined to corms and roots. Furthermore, the carbohydrate/nitrogen relations in timothy plant tops have been studied extensively by Anderson.[4]

[4] *Ibid.*

Dry weights of plant fractions from harvests conducted during 1940 and 1941 are given in table 1. The increase in dry weight of leaves, stems and heads, and corms to applications of nitrogen at early heading in addition to a basic 5-10-5 fertilizer is outstanding. It is noteworthy that corm weight at beginning bloom was approximately 50% greater than at early heading. Since a minor change in corm weight is apparent between beginning bloom and aftermath harvest, indications are that little storage of reserves occurred from aftermath growth when timothy was cut at beginning bloom. If corm weight is an adequate index of stored reserves, the data show that spring application of a complete fertilizer with additional nitrogen at early heading increases reserves of corms.

Percentages of nitrogen and carbohydrates in corms are presented in table 3. Results indicate that nitrogen appli-

Table 4.—Nitrogen and carbohydrates in timothy roots harvested per square foot under different treatments at various times during the 1940 and 1941 growing seasons, average of quadruplicate samples.

Treatment	Dry weight		Nitrogen		Carbohydrates	
	1940	1941	1940	1941	1940	1941
	g.	g.	%	%	%	%
			Sampled at early heading, June			
Check	12.00	9.76	1.14	1.16	35.91	27.47
Check+N at early heading in 1940 only*	—	11.28	—	1.27	—	29.31
400 lbs./A 5-10-5†	11.60	12.96	1.32	1.11	35.06	26.13
400 lbs./A 5-10-5+N at early heading	—	11.52	—	1.23	—	24.32
			Sampled at beginning bloom, July			
Check	5.20	6.96	1.30	1.19	18.92	27.77
Check+N at early heading in 1940 only	8.00	7.68	1.64	1.27	26.84	30.80
400 lbs./A 5-10-5	7.60	6.40	1.33	1.16	26.93	30.62
400 lbs./A 5-10-5+N at early heading	10.00	9.36	1.55	1.35	34.49	29.54
			Sampled during September‡			
Check	4.88	3.52	1.15	1.15	14.47	29.54
Check+N at early heading	7.36	3.76	1.44	1.19	26.33	28.34
400 lbs./A 5-10-5	5.84	4.48	1.14	1.34	18.41	27.34
400 lbs./A 5-10-5+N at early heading	7.28	5.92	1.24	1.29	22.47	28.66

* Nitrate of soda used to supply 36 lbs. N per acre.
† Complete fertilizer applied in spring.
‡ Samples from area harvested at beginning bloom.

Table 5.—Dry weight and percentages of nitrogen and carbohydrates in timothy corms harvested in September 1941.*

Treatment	Number corms	Dry weight g.	Nitrogen %	Carbohydrates %	Carbohydrates/nitrogen ratio
		Hay harvested at early heading stage			
Check	78	5.2	0.92	54.2	58.9
400 lbs./A 5-10-5	90	6.5	0.99	56.6	57.2
400 lbs./A 5-10-5+36 lbs. N. in spring	114	10.3	1.29	53.6	41.6
1200 lbs./A 5-10-5	228	21.2	1.10	51.5	46.8
400 lbs./A 5-10-5+36 lbs. N at early heading	198	15.5	1.10	57.3	52.1
		Hay harvested at beginning bloom			
Check	96	7.6	0.87	54.8	63.0
400 lbs./A 5-10-5	162	10.1	0.97	55.0	56.7
400 lbs./A 5-10-5+36 lbs. N in spring	132	15.1	0.98	58.1	59.3
1200 lbs./A 5-10-5	264	28.9	1.04	53.4	51.3
400 lbs./A 5-10-5+36 lbs. N at early heading	234	24.1	1.06	56.8	53.6
		Hay harvested at late bloom			
Check	138	5.9	0.98	51.8	52.9
400 lbs./A 5-10-5	162	11.1	1.03	54.9	53.3
400 lbs./A 5-10-5+36 lbs. N in spring	168	15.7	1.09	56.0	51.4
1200 lbs./A 5-10-5	312	30.7	1.16	55.9	48.2
400 lbs./A 5-10-5+36 lbs. N at early heading	252	21.4	1.11	55.4	49.9

* Average of 3 replications.

cations at early heading increased the percentage of nitrogen in the corms. Carbohydrate percentages within a sampling date did not show a consistent trend. On a weight basis, however, high fertility appeared to enhance the accumulation of carbohydrates during both seasons. A decrease in percentage of carbohydrates in corms was evident between early heading and beginning bloom dates of harvest. Apparently, the decrease at beginning bloom was due to translocation of carbohydrates to stems and heads for subsequent seed formation or from growth of the axillary buds on the corms.

Data are presented in table 4 concerning nitrogen and carbohydrates by weight in the roots. The small amount of nitrogen and carbohydrates present at beginning bloom and aftermath indicate that roots were relatively unimportant for storage of reserves.

In many perennial plants, autumn is a period of food storage. Results pertaining to corms in table 5 probably represent this condition for timothy. As indicated, harvesting during early heading resulted in an approximate 30% reduction in dry weight of corms when compared with harvests at beginning and late bloom. The decrease was fairly constant regardless of the fertilizer treatment. Number of corms was generally increased as harvesting was

Table 6.—Timothy yield in dry hay per acre with various fertilizer treatments harvested at different stages of maturity, 1941–44.*

Treatment	Year	Yield dry hay in lbs. per acre			
		Early heading	Beginning bloom	Late bloom	Over-all average for fertilizers
Check	1941	974	1922	2378	
	1942	2007	2789	2770	
	1943	706	4294	6147	
	1944	837	1915	2222	
	Average	1131	2730	3379	2413
400 lbs./A 5-10-5	1941	1322	2129	2431	
	1942	3405	3589	3936	
	1943	1121	5036	6603	
	1944	1699	2726	2533	
	Average	1887	3370	3876	3044
400 lbs./A 5-10-5+36 lbs. N in spring	1941	2018	3085	3242	
	1942	3282	4088	3920	
	1943	1992	5264	6605	
	1944	1762	3070	3339	
	Average	2263	3877	4276	3414
1200 lbs./A 5-10-5	1941	2006	3794	3364	
	1942	3644	5204	5487	
	1943	1507	5435	7514	
	1944	1993	3682	3489	
	Average	2287	4529	4963	3887
400 lbs./A 5-10-5+36 lbs. N at early heading	1941	1324	2365	2917	
	1942	3281	4427	4530	
	1943	1019	5297	7042	
	1944	1612	2952	2678	
	Average	1809	3760	4292	3287
Over-all average for stage of harvest		1840	3629	4157	

* Average of 3 replications.

delayed past early heading. The higher fertilizer treatments also increased the number of corms. The above results, which indicate that harmful effects occur to corms from early cutting, support the observations of Waters (11).

Table 5, presenting data on additional fertilizer treatments, further indicates (see table 3 also) that management practices can be used to increase the dry weight and in most cases nitrogen and carbohydrate content of corms prior to winter dormancy. Fertilizer applications of 1,200 pounds per acre of 5–10–5 and 400 pounds per acre of 5–10–5 with 36 pounds of nitrogen at early heading were most successful in this respect.

Yields of hay for the period 1941 through 1944 are given in table 6. Protein yields are given in table 7. The data support the findings of Sprague and Hawkins (8) in that the spring applications of nitrogen gave increases in yield. The results from this experiment indicated that spring applications of nitrogen gave increases in yield but were not effective in increasing the protein content of timothy when measured as percent of protein in the forage at early heading. Yield response, however, was found to have been markedly influenced by precipitation during the spring months. The relation of early harvest to high protein hay is clearly indicated in table 7.

The data in tables 6 and 7 show marked differences in yield of forage and protein due to fertilizers, time of harvest, and years. The significance of the appropriate comparisons for this study were made by use of the F test (5) for single degrees of freedom. The statistical analyses indicated that the yield of hay was not significantly increased by the application of 400 pounds of nitrogen from nitrate of soda applied in the spring, when compared with the additional nitrogen applied at the early heading stage. On the other hand, 36 pounds of extra nitrogen at early heading did produce a significant increase in yield of protein when compared with the 400 pounds of 5–10–5 applied in the spring. The application of additional nitrogen in the spring increased both herbage and protein yield. At the beginning bloom stage, the increased protein yield from nitrogen application at early heading was due to a higher percentage of protein in the forage and greater yield.

The yield of both forage and protein was significantly affected by the stage of harvest. The yield of forage (table 6) as an average of all years and fertilizers, progressively increased from early heading to late bloom. Protein (table 7), on the other hand, was lower in the forage cut at late bloom as compared with the other two stages of harvest. It should be pointed out that the interaction of stages of harvest and fertilizers was significant for protein content of the forage.

Records of plant species persistence showed that extra nitrogen treatments resulted in marked improvement in the productive life of the timothy stand (data not included). At the end of the 4-year period, however, the stand of timothy was unsatisfactory except where the 1,200 pound per acre of 5–10–5 had been used under the beginning

Table 7.—Protein yield in pounds per acre from timothy under various fertilizer treatments, harvested at different stages of maturity, 1941–42.[1]

Treatment	Year	Early heading	Beginning bloom	Late bloom	Over-all average for fertilizers
Check	1941	110.0	157.6	152.2	
	1942	188.2	226.7	189.5	
	Average	149.1	192.2	170.8	176.3
400 lbs./A 5-10-5	1941	160.2	189.5	155.6	
	1942	403.1	323.7	264.5	
	Average	281.6	256.6	210.0	249.4
400 lbs./A 5-10-5+36 lbs. N. in spring	1941	264.3	265.3	236.6	
	1942	419.5	344.6	293.2	
	Average	341.9	304.9	264.9	303.9
1200 lbs./A 5-10-5	1941	256.1	352.8	248.9	
	1942	454.4	482.4	429.7	
	Average	355.2	417.6	339.3	370.8
400 lbs./A 5-10-5+36 lbs. N at early heading	1941	153.6	283.5	253.8	
	1942	391.1	525.0	404.1	
	Average	272.3	404.3	328.9	335.2
Over-all average for stage of harvest		283.4	315.1	262.8	

[1] Average of 3 replications.

bloom and late bloom stage of harvest. Harvesting at the early heading stage, even where extra nitrogen and extra fertilizer were used, resulted in the poorest stands of timothy. Weed encroachment was most rapid on plots harvested at early heading. Extra nitrogen did, however, reduce to some extent the harmful effect of early cutting on persistence.

SUMMARY

Fertilizer applications were conducive to the development of a shorter, more compact root system. Roots appeared to have a minor function in reserve storage.

Applications of nitrogen in the spring and at early heading in addition to a basic 5-10-5 fertilizer (400 pounds per acre) was usually effective in increasing the dry weight and nitrogen and carbohydrate content of timothy corms. Increasing the rate of application of the basic 5-10-5 fertilizer to 1,200 pounds per acre was also successful in this respect.

In general, reserves in corms were correlated with persistence in that the best timothy stands were maintained with fertilizer treatments which enhanced nitrogen and carbohydrate content in corms at autumn.

Harvesting at early heading was conducive to a reduction in the dry weight of corms regardless of fertilizer treatment and resulted in the poorest stands of timothy. Harvesting at the beginning bloom stage gave the most satisfactory yields of desirable forage. Delaying harvest until late bloom resulted in an increased forage yield of much lower quality and did not greatly improve the storage of reserves.

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Notes

A SCALE RACK AND PROCEDURE FOR RAPID, PRECISE CATTLE WEIGHTS[1]

THE use of animal performance as criteria for pasture evaluation with grazing trials requires the minimum of error in animal weights. The usual basis for expressing beef production refers to gains and losses of animal tissue weight expressed as gain per head, rate of gain or gain per acre. Differences in weights of an individual steer, resulting from fill and shrink variations, may completely overshadow animal gains and losses in tissue weight. Procedures for handling and weighing experimental animals must be designed to minimize errors due to these large variations. This requires careful, uniform handling of animals during the preweighing or "shrink" period combined with rapid, precise individual weighings taken within the shortest possible time lapse.

A dual-gated scale rack combined with a working chute and sliding "cut-off" gate have been effective means of accomplishing rapid, precise weighing of experimental animals at the Southeast Oklahoma Pasture Fertility Research Station, Coalgate, Okla. The 70 steers in the present Main Station experimental herd, divided into 18 different lots, are weighed individually by separate pasture lot in less than 1 hour. Only two men work the animals. One weighs and works both scale rack gates controlling the animal on the scale. The other moves the animals up the working chute and, using a sliding gate, cuts off one steer into a waiting space at the scale. Both men move the animals by lot from their corral pens to the scale chute. The corral pen gate of the lot being weighed is left open, blocking the corral alleyway, allowing the animals to wander back to their pen after weighing.

The scale rack is 4½ by 9 by 5 feet. The sides and ends including the gate frames are made of welded ¾ inch pipe with each section made separately and fitted together with ½ inch steel pins. The gates easily slide up and back on roller bearing wheels in guide tracks (figure 1). A three-pulley arrangement for each gate allows the man at the scale to easily control both gates with little effort and no loss of time or movement. Steers at this station are number branded on the right hip, allowing quick identification as they move onto the scale. The open pipe rack allows a quick, thorough observation of the animal for causes that require additional attention such as cuts, keratitis, screw worm infestations, etc. The man working the cattle in the chute usually has ample time to obtain fecal samples for internal parasite surveys. Samples are collected in small ice cream cartons and identified with the depositing animal's number.

The pre-weighing shrink is obtained at this station by walking each pasture lot of animals to the corral holding pens at sunset preceding the weighing date and holding overnight without feed or water. The animals are weighed at dawn the following morning and moved back to the experimental pastures as soon as practical after weighing.

The use of a scale rack provided with sliding gates and working chute has provided means for rapid, effective handling and weighing of large experimental herds using only a two-man working team. The use of this equipment,

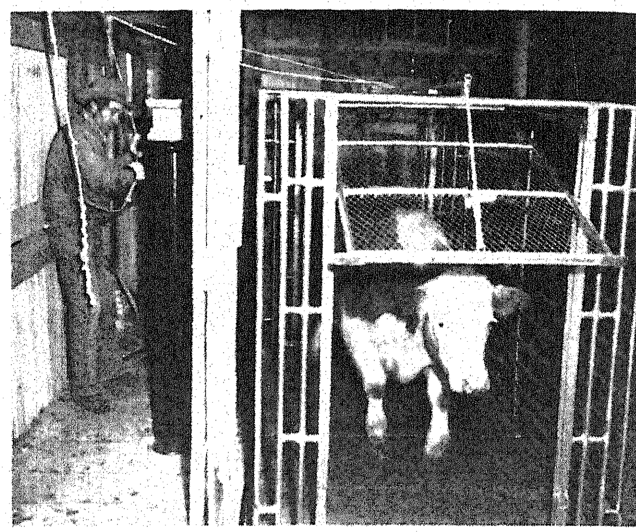


FIG. 1.—Exit view of dual gated scale rack that provides rapid, precise weighing of large numbers of experimental animals with only a two man crew. A working chute with a sliding cut-off gate controls experimental steer lots onto the scale individually. The 9 by 4½ by 5 foot rack is mounted on a 6,000 pound capacity standard double beam single animal stock scale.

combined with a uniform procedure of obtaining pre-weight shrink, does much to increase precision and reliability of animal weights in grazing experiments concerned with beef gains.—J. Q. LYND, *Oklahoma A. and M. College.*

[1] Received April 7, 1955.

TRANSFERRING THE *Ga*˙ FACTOR FOR DENT-INCOMPATIBILITY TO DENT-COMPATIBLE LINES OF POPCORN[1]

POPCORN seed production in the corn belt area without contamination by dent pollen is a serious problem even with proper isolation. A small percentage of contamination often occurs in seed fields grown under ideal conditions. This requires extra expense to separate pop × dent hybrid ears from the commercial crop.

Most popcorn lines isolated from South America, Superb, and Japanese Hulless varieties set little or no seed when pollinated by dent pollen. In contrast, lines isolated from Supergold, Golden Amber, Queen's Golden, and Yellow Pearl varieties have normal seed set when pollinated by dent pollen. Pollen from Supergold, Golden Amber, Queen's Golden, and Yellow Pearl lines will not affect fertilization of South American, Superb, and Japanese Hulless lines. Pollen from lines of all popcorn varieties is effective on dent corn.

Nelson[2] presented information on the inheritance of cross-incompatibility, later substantiated by Whiteley.[3]

[1] Contribution from the Agronomy Department, Iowa Agr. Exp. Sta., Ames, Iowa. Project 345. Approved for publication as Journal Paper J-2742. Received April 7, 1955.

[2] Nelson, Oliver E., Jr. Non-reciprocal cross-sterility in maize. Genetics 37:101–124. 1952.

[3] Whiteley, Joseph R. Cross-incompatibility in maize. Unpublished Ph.D. thesis, Iowa State College Library, Ames, Iowa. 1953.

Most dent-incompatible popcorn lines are of Ga^sGa^s genotype while the dent-compatible popcorn lines and most dent corn lines are *ga ga*. The following results usually are obtained when crosses are made between the different genotypes.

Cross	Seed Set	Genotype of Progeny
1. $Ga^sGa^s \times ga\ ga$	None	------
2. $ga\ ga \times Ga^sGa^s$	Normal	Ga^sga
3. $Ga^sga \times ga\ ga$	Normal	Ga^sga, $ga\ ga$
4. $Ga^sGa^s \times Ga^sga$	Normal	Ga^sGa^s
5. $Ga^sga \times Ga^sga$	Normal	Ga^sga, Ga^sGa^s

In cross number 4, the *ga* gamete does not function on Ga^sGa^s stylar tissue. In cross number 5, the *ga* gamete seldom effects fertilization on stylar tissue of Ga^sga^s constitution when competing with Ga^s gametes. However, unusual environmental influences and genetic modifications of the alleles may result in fertilization by some *ga* gametes.

By the use of the back cross method, the Ga^s factor may be transferred easily into lines of the *ga ga* constitution. Since the heterozygote cannot be identified phenotypically, a technique to identify such plants is helpful in accomplishing desired back cross results.

The following technique has been used successfully at the Iowa Agriculture Experiment Station

	Ear Parent	Pollen Parent	Genotype of Progeny
1st year	$ga\ ga$	$\times\ Ga^sGa^s$	Ga^sga
2nd year	Ga^sga	$\times\ ga\ ga$ (recurrent parent)	1 Ga^sga : 1 $ga\ ga$
3rd year	Ga^sga	$\times\ ga\ ga$ " "	1 Ga^sga : 1 $ga\ ga$
	$ga\ ga$	$\times\ ga\ ga$ " "	2 $ga\ ga$

In the third year BC_1 plants pollinated by the recurrent parent also are outcrossed as male parents to a Ga^sGa^s tester stock. Pollen from heterozygous plants will produce fertile ears on the tester stock while pollen from homozygous *ga ga* plants will not fertilize the tester. On the basis of the outcross test, *ga ga* plants back crossed to the recurrent parent are discarded and plants whose pollen results in normal fertilization on the tester are assumed to be heterozygous for the Ga^s factor. Back crossed seed on ears of these plants is grown the following year. The same procedure for identifying Ga^sga and *ga ga* plants is used in following generations until the recovered lines are sufficiently like the recurrent parent. At this time the plants are selfed and also outcrossed to the tester.

In order to isolate homozygous progeny from the selfed heterozygous plant, a rather simple scheme is used which avoids the need of testing progeny of S_1 plants. Ten to 15 S_1 plants are pollinated by a purple aleurone stock of *ga ga* constitution. On the following day the plants are selfed. In general, plants of Ga^sga or *ga ga* genotype have all or a considerable number of purple kernels. Plants of Ga^sGa^s genotype have no purple kernels or only a few near the tip of the ear, the remainder being of normal color.

Although this method has been used only in transferring dent incompatibility to popcorn lines, the same principle and techniques would be applicable in transferring dent-incompatability to selected dent corn inbreds, such as waxy endosperm, to avoid contamination with normal-starch lines in crossing plots and in commercial waxy corn fields.—WALTER I. THOMAS, *Associate in Farm Crops, Iowa State College.*

Book Reviews

STANDING ROOM ONLY

By Karl Sax. Boston, Beacon Press. 206 pp. 1955. $3.00.

"Standing Room Only" by a Harvard Professor should be required reading for every literate man and woman. Too long man has ignored a basic teaching of nature. He has taken the easy and near sighted view, yes even the selfish view. A selfless deed is one that will leave this world a better place in which to live. As parents, we jealously activate some responsibilities to our children. We desire for them better opportunities than we have in the pursuit of health, happiness and the finer things of life; and yet too often choose to ignore one aspect of this subject which may vitiate all others.

Place a male and female fruit fly in a stoppered bottle containing a bit of ripened banana and what happens? In a few days the bottle is filled with flies, the banana is consumed and the flies die. This simple illustration teaches one inexorable natural law. If rate of reproduction outruns the resources to sustain it, only one thing can happen—disaster for the individuals and the species. If man is to climb higher and higher in the social scale of life or, put another way, approach nearer and nearer to the level we think the Creator intended, he must have a suitable environment. Is such an environment possible in a country bursting at the seams from population pressure?

Many will disagree with Dr. Sax's position, some on religious grounds, some for political reasons and others as a matter of expediency. I for one have never been able to reconcile the idea that there should be moral, religious or political discrimination in the natural laws we seek to manipulate as long as that manipulation is beneficial to man, present and future. On the contrary if man is aware of the natural laws, he would be foolish, indeed, to disregard them. Nature maintains a balance among biological forms by "survival of the fittest". Man should be intelligent enough to avoid situations that will inevitably lead to just such a rigorous struggle among his own species. "Be fruitful and multiply" should never be interpreted to be overfruitful and die.

No one can read Dr. Sax's book and escape giving serious thought to a problem now acute in several countries and just over the horizon in others. To quote a Chinese proverb, "It is later than you think."—R. J. GARBER

CORN AND CORN PRODUCTION

Edited by George F. Sprague. New York, Academic Press, Inc. 699 pp. 1955. $11.50.

This publication represents Vol. V of *Agronomy*, a series of Monographs prepared under the auspices of the American Society of Agronomy, and represents a noteworthy addition to the series of publications already sponsored by the Society.

There are 16 chapters, contributed by 14 different authors. The chapter headings and authors indicate the broad scope of treatment as follows:

I. History and origin (P. WEATHWAX and L. F. RANDOLF); II. Vegetative morphology (J. E. SASS); III. Structure and development of reproductive organs (WEATHERWAX); IV. The cytogenetics of maize (M. M. RHOADES).

V. Corn breeding (G. F. SPRAGUE); VI. Mineral nutrition of corn (J. D. SAYRE).

VII. Climatic requirements (R. H. SHAW); VIII. Corn culture (G. H. STRINGFIELD).

IX. Production of hybrid seed corn (J. M. AIRY); X. Popcorn (A. M. BRUNSON); XI. Sweet corn (G. M. SMITH); XII. Dis-

eases of corn (A. J. ULLSTRUP); XIII. The most important corn insects (F. F. DICKE); XIV. Industrial utilization (G. F. SPRAGUE); XV. The nutritive value of corn (B. H. SCHNEIDER); and XVI. The world production of corn (G. F. SPRAGUE).

Each chapter includes a substantial list of literature citations. The prime emphasis has been placed on conditions and developments within the United States of America in an attempt to restrict coverage to the area where research on corn has received the greatest emphasis. Information from other parts of the world largely has been omitted in order to keep the size of the volume within reasonable limits.

Eight of the contributors are members of the Agricultural Research Service, U.S.D.A. The chapter on production of hybrid seed corn, significantly, was prepared by the production manager of a large seed company in Iowa and is based on hard, practical experience. It is certainly true that in many parts of the world, as it was in the U.S.A., the potential contributions that hybrid corn may be able to make will be depend upon success in developing workable plans and procedures for seed production, processing and marketing.

As recognized by the editor it is difficult to obtain uniformity of treatment, especially when co-ordination could be accomplished only by correspondence. Another editor may have chosen a somewhat different array of topics and emphasized some aspects more than has been done in this volume. Allowing for differences of opinion in these respects, this volume is a well balanced coverage of the maize plant and its use as a farm crop in the three broad divisions of breeding, production, and utilization.

This Monograph provides workers everywhere with a distillation of knowledge and experience that may be expected to exercise a marked stimulating influence in all aspects of research concerning the maize plant. In those chapters where they serve a useful purpose, illustrations have been freely used.

The editor and his co-authors are to be warmly congratulated. The publisher also has maintained a high standard of production. This monograph is confidently recommended to all who have an interest in corn and corn production.—N. P. NEAL.

MICROBIOLOGY, AN INTRODUCTION

By Ernest Gray. New York. Philosophical Library. Inc. 175 pp. (5 by 7 in.) illus. 1955. $3.75.

This compact, little volume gives the student or general reader a simple introduction to microbiology. In all respects, it carries out its purpose most competently. It is intended to provide a foundation for students who intend to specialize in one of the many specialized fields of microbiology. Not radically different from most standard introductory texts, this volume has the following 11 chapters: biology of micro-organisms; culture and control of microorganisms; the host-parasite relationship of cells; the viruses; the bacteria; yeasts, moulds, and fungi; algae; protozoa; soil microbiology; microbiology of inland waters and the sea; and applied microbiology.

The discussion on soil microbiology covers soil bacteria, the nitrogen cycle, non-symbiotic nitrogen-fixing bacteria; symbiotic nitrogen fixation, soil fungi, soil algae, and the influence of soil treatments on microbiological populations. The chapter on applied microbiology discusses the various actions in food spoilage and preservation, brewing, wine making, silage fermentation, and flax retting.

The author is chief bacteriologist of Bayer's Biological Institute, Exning, England.

SOIL WARMING BY ELECTRICITY

By R. H. Coombes. New York, The Philosphical Library. 116 pp. (5 by 7 in.) 12 pp. illus. 1955. $4.75.

With the great strides in rural electrification during the past 25 years, farmers have revolutionized many of their major operations. One of the more recent electrical applications, introduced during World War II, is electric heating cable to warm the soil in green house seed beds and outdoor frames. Its use enables the farmer or nurseryman to get earlier start with seedlings than the seasonal cycle permits and often to get an additional crop. Its use is not limited to commercial growers, but is widely used, at least in the United States, by home gardeners.

This book gives instructions on the installation of high and low voltage systems, the operation, and general use of the cables. The economics of soil warming is also discussed, and the author points out the removal of additional soil nutrients from plots by the extra burden made possible through the use of warming cable necessitates closer attention to the maintenance of soil fertility.

The second half of the book is devoted to cultural practices recommended in conjunction with soil warming for various fruits, vegetables, and flowers. The possibilities of using the soil warming technique are also discussed for such as yet untried fields as grape culture, mushrooms, peaches and nectarines, rhubarb, soybeans, groundnuts, and pineapple.

ANNUAL REPORT OF EAST MALLING RESEARCH STATION

The Kent Incorporated Society for Promoting Experiments in Horticulture. East Malling, Maidstone, Kent, England. 170 pp. illus. 1954. 12 shillings 6 pence.

This annual report issued during the past summer covers the period of Oct. 1, 1953 to Sept. 30, 1954. The first two parts survey the management of the experimental farm, the crops harvested, and research conducted during the report period. Twenty-four papers are included in the third part dealing with rootstocks, propagation, incompatability, black currant varieties and pruning, frost incidence, pot culture of apples under glass, growth inhibitors, virus diseases, fungicides, and other topics. The report is available at the above price from the Secretary, East Malling Research Station, near Maidstone, Kent, England.

THE AGRICULTURAL REGIONS OF THE UNITED STATES

By Ladd Haystead and Gilbert C. Fit. Norman, Okla. The University of Oklahoma Press. 288 pp. illus. 1955. $5.00.

An Oklahoma university history professor and an agricultural agent for the Standard Oil Co. have collaborated on this popular presentation of U. S. agricultural statistics. As the title indicates, the book is divided into 12 main chapters, each dealing with a more or less distinct geographical–agricultural region of the country. The great wealth and diversity of American agriculture is easily taken for granted. Ordinarily the average citizen can begin to appreciate its great diversity and wealth only by visiting each region, or by reading such an informative discussion as this. The authors possess a detailed knowledge of the agricultural development of the United States, and relate the major problems that each of the regions have faced; those of New England and the Deep South should be of particular interest to readers outside those areas where farm problems have been of a different nature and scope. The book is well documented with statistics from the U. S. Census of Agriculture, and it is to the authors' credit that they have converted statistics into a story that has both color and impact. Its weakness lies in the impression a reader is likely to get that much of the wealth and scope of U. S. agriculture "just happened." Since the book is not primarily a history of U. S. agriculture, this is not a great shortcoming. This book could serve well as a valuable aid to those who tell the story of agriculture to the U. S. and world-wide public.

AMERICAN POTATO YEARBOOK

C. S. Macfarland Jr., Ed. and Pub. Westfield, N. J. 84 pp. 1955. $2.00.

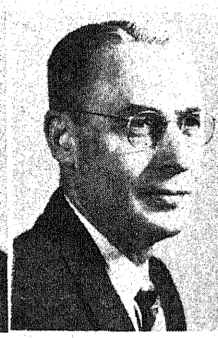
The 1955 edition of the American Potato Yearbook contains 84 pages of useful information to the potato grower, shipper, jobber, and research specialist. It contains a current list of references to potato culture in the United States and Canada, and information on U. S. standards for potatoes. A new feature is the 1955 Onion Supplement with recently published articles on onions, leading producing areas, and other information. The Yearbook also tells where to get bulletins and leaflets on all phases of the potato industry.

Agronomic Affairs


Johnson


Mott


Thorne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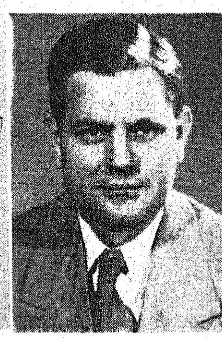
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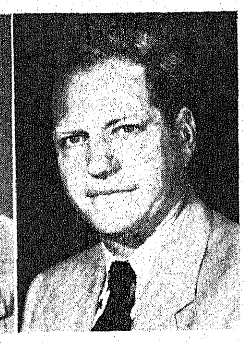

Nelson

Pictured above are the new officers of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. Left to right: I. J. Johnson, Iowa State College, president, ASA; G. O. Mott, Purdue University, president, CSSA; D. E. Thorne, Utah State Agricultural College, president, SSSA; A. G. Norman, University of Michigan, vice president, ASA; Herbert Kramer, Purdue University, vice president, CSSA; and L. B. Nelson, USDA, Beltsville, Md., vice president, SSSA. Past presidents of the Societies are G. G. Pohlman, West Virginia University, ASA; M. B. Russell, University of Illinois, SSSA; and G. H. Stringfield, Ohio Agricultural Experiment Station, Wooster, CSSA.

MEETINGS

Oct. 10–13, National Clay Minerals Conference, Pennsylvania State University.
Oct. 16–19, Society of American Foresters, Portland, Ore.
Oct. 18–20, Entomological Society of Canada, Fredericton, New Brunswick.
Oct. 24–26, National Conference of Standards, Washington, D. C.
Nov. 6–12, International Crop Improvement Association, Winter Haven, Fla.
Dec. 26–31, American Association for the Advancement of Science, Atlanta, Ga.

DONALD HANWAY HEADS NEBRASKA DEPARTMENT

Donald Grant Hanway was appointed chairman of the University of Nebraska agronomy department on Aug. 5.

Dr. Hanway received the B.Sc. degree with distinction from Nebraska in 1942, the M.Sc. in 1948, and the Ph.D. from Iowa State College in 1954. He was born on a farm in western Nebraska in 1918, and taught in the rural schools of Morrill County for 4 years. In World War II he served in the Army Air Force Radar Maintenance with the rank of captain.


D. G. Hanway

A member of the agronomy staff at Nebraska since 1947, Dr. Hanway holds membership in Alpha Zeta, Gamma Sigma Delta, Sigma Xi, Phi Kappa Phi and Phi Beta Kappa. He was faculty sponsor of the Nebraska Agronomy Club which was selected as the outstanding Agronomy Club of the nation in 1953 by the American Society of Agronomy, and is considered an outstanding student leader and adviser. He is the leader of the Soybean Project in the Nebraska Agricultural Experiment Station.

He replaces F. D. Keim who has been temporary chairman since April 15 when E. F. Frolik, the former chairman since 1952, was appointed associate director of the experiment station.

SOCIETIES HAVE SUCCESSFUL CALIFORNIA MEETING

The 47th annual meeting of the American Society of Agronomy drew 1,077 officially registered delegates to the University of California campus at Davis Aug. 15–19. More than 600 students, press representatives, special guests, and wives and children increased the over-all attendance to one of the highest for a Society meeting.

In addition to the general business meetings of the American Society of Agronomy, Soil Science Society of America, Crop Science Society of America, the Agronomic Education Division, and the divisional sessions, tours were conducted to the alfalfa seed producing areas of California, the agronomy farms, the irrigation demonstration fields, and the Coastal Range area.

A report of the Societies' officer elections announced during the meeting appears elsewhere on this page. New divisional vice chairmen elected during the meeting are as follows:

Division I, soil physics, R. D. Miller, Cornell Univ.; Div. II, soil chemistry, C. A. Bower, USDA, Riverside, Calif.; Div. III, microbiology, G. D. Thornton, Univ. of Florida; Div. IV, fertility, A. H. Ohlrogge, Purdue Univ.; Div. IV–A, organic soils, A. E. Kretschmer, Univ. of Florida; Div. IV–B, plant nutrients, A. H. Bower, Swift & Co., Chicago; Div. V, classification, F. C. Westin, South Dakota Agr. Coll.; Div. V–A, Forest soils, S. P. Gessel, Univ. of Washington; Div. VI, conservation, J. R. Johnston, USDA, Amarillo, Tex.; Div. VII, genetics and cytology, J. Ritchie Cowan, Oregon State Coll.; Div. VIII, physiology and ecology, R. E. Wagner, USDA, Beltsville, Md.; Div. IX, crop production and management, Kling Anderson, Univ. of Kansas; Div. X, seed production, and technology, F. G. Parsons, Univ. of California, Davis; Div. XI, turfgrass management, Gene Nutter, Univ. of Florida; Div. XII, weeds and weed control, Glenn Klingman, North Carolina State Coll.; and Div. XIII, agronomic education, Harold E. Jones, Univ. of Minnesota.

ICIA MEETS IN FLORIDA NOV. 6–12

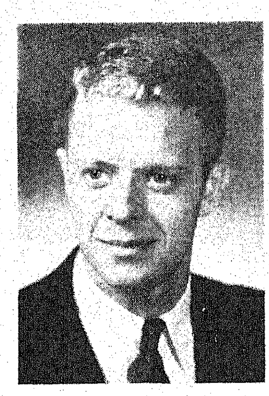
The International Crop Improvement Association will hold its 1955 meeting Nov. 6–12 at Winter Haven, Fla. The tentative program is as follows:

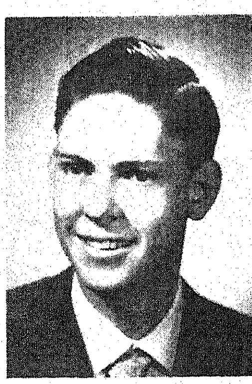
Trip to Cypress Gardens, Sunday, Nov. 6; agricultural tour of Winter Haven area, Monday, Nov. 7; committee growers, and directors' meetings, Tuesday, Nov. 8; commodity committee meetings, Wednesday, Nov. 9; general program, Nov. 10, 9 a.m., and annual banquet 7 p.m.; annual business meeting, Nov. 11; trip to Silver Springs, Nov. 12.

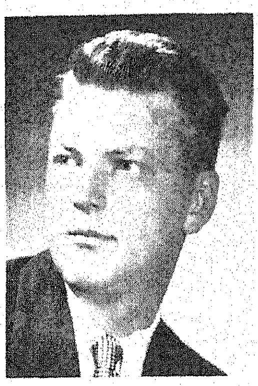
Room reservations should be made with Harry Carroll, Haven Hotel, Winter Haven, Fla.

ANNUAL MEETING REPORTS WILL BE PUBLISHED IN THE DECEMBER ISSUE

The December issue of the *Agronomy Journal* will publish a complete report of the 1955 meetings of the American Society of Agronomy. Included will be central office reports, minutes of the general meetings, and all committee and representative reports of the ASA and the Crop Science Society of America. Similar reports for the Soil Science Society of America will appear in the January 1956 issue of *SSSA Proceedings*.


Donald Faulkner


Charles Murphy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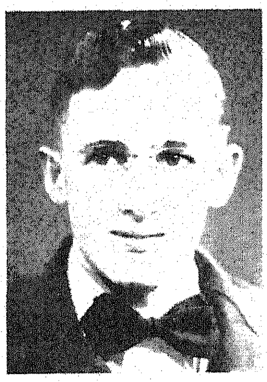
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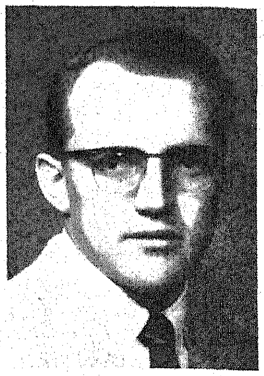
David James

CORNELL STUDENT WINS ESSAY CONTEST

DONALD M. FAULKNER, Cornell university student from Richmond, Va., won first place in the annual essay contest sponsored by the American Society of Agronomy. The 10 winners in the 1955 contest were announced at the annual banquet of the American Society of Agronomy Aug. 17 in Davis, Calif.

Second and third place winners are CHARLES F. MURPHY, Iowa State College student from Ames, Iowa, and DEAN L. SWEDLUND, also of Iowa State College, whose home is in Stratford, Iowa.

Other winners in order of their placement are WILLIAM R. DUFFER, Ada, Okla., Oklahoma A&M Coll.; DON W. FORCE, Gillette, Wyo., Univ. of Wyoming; DAVID W. JAMES, Logan, Utah, Utah State Agr. Coll.; DONALD C. PETERSON, Kansas State Coll., Manhattan; BRUCE W. CONE, Willow Springs, Ill., Univ. of Illinois; JACK LESTER, Riverton, Wyo., Univ. of Wyoming; and LUTHER H. ROBINSON, JR., Lyons, N. Y., Cornell Univ.

From award money donated by the American Potash Institute, the three top winners attending the meeting each receive $50 toward their meeting expenses. They also receive $25 each for publishing their essays in WHAT'S NEW IN CROPS AND SOILS. The next three winners each receive $15.00, and all 10 winners each receive a subscription to WHAT'S NEW IN CROPS AND SOILS.

FOUR WIN MEMBERSHIP DRIVE AWARDS

Four members of the American Society of Agronomy, one from each regional branch, have received a $50 U. S. savings bond each for obtaining the highest number of new active memberships in their branch. A total of 39 new members were solicited in the membership drive during the past summer. Winners of the bonds are: S. M. RALEIGH, Pennsylvania State University; H. D. FOTH, Texas A. & M. College, now of Michigan State University; F. P. GARDNER, Ohio State University, and R. E. DANIELSON, Colorado A and M College.

MICHIGAN HONORS C. E. KELLOGG

CHARLES E. KELLOGG, assistant administrator for Soil Survey, USDA SCS, since 1934, received an award for distinguished service from Michigan State University on Aug. 19, on the occasion of the university's centennial anniversary.

The citation accompanying the award reads, in part:

"Throughout your long and distinguished career as a soil scientist, you have labored effectively to benefit mankind the world over by furthering the knowledge and use of the soil."

Dr. Kellogg received his B.S. degree from Michigan State in 1925 and the Ph.D. degree in 1929. He was on the staff of the University of Wisconsin and of North Dakota Agricultural College before coming to the USDA in 1934.

MICHIGAN STUDENT DIES

KENNETH M. COOPER, graduate student in soil science in Michigan State University, died July 23, 1955 in a Reed City, Mich., hospital from injuries received in an automobile accident.

Mr. Cooper was born May 15, 1932 at Floyd, N. Mex. In 1954 he received a B.S. degree, with honors, in chemistry from Eastern New Mexico University. He had completed most of the requirements for the M. S. degree.

His major interest was in soil genesis and classification. At the time of his death, he was employed by the Michigan State Conservation Department in making a cooperative soil survey of Osceola County, Mich.

CHARLES A. HELM OF MISSOURI DIES

CHARLES A. HELM, professor of field crops at the University of Missouri, died of a heart attack on July 24. He had been appointed chairman of the field crops department and would have assumed that office Sept. 1, when W. C. ETHERIDGE retired. M. S. OFFUT has been appointed department chairman.

Prof. Helm was born at Sheldon, Mo., in 1889. He received the B.S. degree from the University of Missouri and the M.S. degree from the University of Nebraska. He returned to Missouri following graduate studies in 1916 and was in the farm crops department until his death.

Prof. Helm served as secretary of the Missouri Crop Improvement Association, and director to the International Crop Improvement Association since the early 1930's. At the time of his death, he was chairman of the cotton committee and a member of other ICIA committees.

BRYCE GRAY DIES IN MICHIGAN

BRYCE C. GRAY, former graduate student of Ohio State University, died after a short illness at Detroit, Mich., on May 9, 1955.

He was born near Detroit on Aug. 13, 1928. He received a Bachelor of Science degree from Michigan State College in 1950, Master of Science degree from the University of Massachusetts in 1952, and the Doctor of Philosophy degree from Ohio State University in 1954.

Dr. Gray's graduate work was in agronomy in the field of Soil Chemistry and Plant Physiology. He had recently completed his Ph.D. dissertation on "Factors Affecting Calcium–Boron Ratios in Plants". Prior to his illness he had taken a position with the Agricultural Research Service, Beltsville, Md.

G. W. DEMING DIES IN COLORADO

G. WARREN DEMING, U.S.D.A. agronomist in sugar plant investigations, died June 19, 1955 at Fort Collins, Colo.

Mr. Deming was born at Fleming, Ohio, March 31, 1890, and was graduated from the University of Nebraska in 1918. He did post-graduate work at Colorado A & M College between 1921 and 1930. In military service during World War I, he was married to the former Miss Gratia Horan of Fairmont, Nebr. in 1918. He is survived by three children.

Mr. Deming was on the staff of the Colorado Agricultural Experiment Station from 1921 to 1930 working in field crops. In 1931 he was appointed assistant agronomist for the U.S.D.A. in the office of sugar crops and beets at the Colorado Station. He is recognized for his work in selecting and purifying some 300 inbred lines of sugar beets which are the basis of the beet breeding program conducted by the U.S.D.A. and commercial sugar companies. In this field, he has done outstanding work. He was a member of the American Society of Agronomy and American Society of Sugar Beet Technologists.

NEWS ITEMS

ROBERT H. ENGLE has been on an FOA assignment since June as fertilizer adviser to the Indian government. In April, he retired from the National Fertilizer Association after serving as agronomist and director of visual aids for 17 years.

—A—

R. A. SCHWARTZBECK joined the Texas Agricultural Experiment Station staff July 1 as assistant agronomist at the Winter Haven station. He received his B.S. and M.S. degrees from the University of Wisconsin.

RUSSIANS VISIT IOWA AGRONOMY FARM

Iowa State College Photo

Iowa State College was one of the first major stops on the itinerary of the Russian agricultural research and administrative personnel who toured U. S. farm areas in August. Shown above is a small group of the visitors with Iowa State College personnel on a tour of the college agronomy farm. Left to right, C. P. WILSIE, Iowa State forage crops breeder; FLOYD ANDRE, Iowa State dean of agriculture; ROY KOTTMAN, Iowa State associate dean of agriculture; and four unidentified Russians.

J. K. LEASURE, associate professor and associate agronomist at the University of Tennessee, Knoxville, resigned July 1, 1955 to accept a position as head of the Herbicide Research Section at the Dow Chemical Co. research laboratory in Midland, Mich.

—A—

BOYD R. CHURCHILL of the Michigan State University department of farm crops was selected as recipient of the 1955 Distinguished Teacher's Award for the School of Agriculture and for the entire Michigan State University. This award consisted of a citation, a gold medal, a wrist watch and a $500 check.

—A—

E. J. WHEELER has returned to East Lansing, Mich. from the University of Ryukus, Okinawa, where he headed the Michigan State University mission to that university. Prof. Wheeler will resume his responsibilities in potato breeding and variety evaluation.

—A—

H. R. PETTIGROVE is in Medellin, Columbia, S. A., from June 1, 1955 to July 1, 1957 as a member of the Michigan State University mission to Columbia. Prof. Pettigrove is establishing a farm crops curriculum at the university. He will return on July 1, 1957. WILLIAM F. HUEG, JR. has joined the staff of the Department of Farm Crops of Michigan State University as an instructor. He has been at Alfred University, Alfred, N. Y., and will assume teaching responsibilities during Prof. Pettigrove's absence and will work toward the Ph.D. degree.

—A—

STERLING B. WEED became assistant professor in agronomy at Cornell University Aug. 10. He received his Ph.D. at North Carolina State College in June, 1955, and will teach elementary soils and act as undergraduate student advisor in Soils.

—A—

On July 1, 1955, Extension Soil Conservationists, H. M. WILSON and HARRY KERR, were transferred from the Office of the Director of Extension to the Department of Agronomy at Cornell University. They are now part of the Agronomy Extension unit.

—A—

The Agronomy Department at Cornell University has initiated a comprehensive research program on nitrogen fertilizers, their behavior in the soil, and field applications, under a grant from the Sun Oil Co. Four new staff members added to assist with the research are:

H. F. KREIZINGER who completed his Ph.D. from Cornell University in July, 1955 and has been appointed assistant professor to assist with field work on the effect of various nitrogen sources on the yield of field crops.

R. J. MARRESE who received his M.S. degree from Cornell in June, 1955 and is now research associate with responsibility for field experiments on the response of forage crops to nitrogen fertilization.

JOHN CLARK from the Canadian Department of Agriculture who will become assistant professor to conduct research on reactions of nitrogenous and phosphate fertilizers with soil.

LAWRENCE G. MORRILL formerly of Utah State, who assumed duties as research associate on Sept. 15 to conduct research on the factors affecting the rate of nitrification in soils.

—A—

GORDON W. ARNOLD, University of Wyoming agronomist, has been named home staff coordinator of the Afghan program at the University. Mr. and Mrs. Arnold returned recently to Laramie after a 6-month stay in Kabul, Afganistan, where he had served as research agronomist at the Kabul Central Experiment Station.

T. H. GOODDING, who retired in July from the University of Nebraska's agronomy department, is now with the University of Nebraska Faculty in Turkey. Under an ICA contract agreement between the University of Nebraska and Ankara University, he will have teaching and advisory duties in agronomy. He will also help select those who will come to the United States for training, and will aid in planning the proposed new Ataturk University in eastern Turkey.

—A—

The following promotions are announced in the Iowa State College agronomy department: W. V. BARTHOLOMEW, DARREL METCALFE and WAYNE SCHOLTES, to the rank of professor; John Hanway and Wilbert A. Russell, to associate professor; and Robert Prill to assistant professor.

—A—

H. P. COOPER, professor of agronomy at South Carolina Agricultural College, Clemson, was one of three agricultural leaders of the state recognized at the college's Farm and Home Week in August. An agronomist and soil scientist, he was director of the South Carolina Agricultural Experiment Station for 17 years.

—A—

PERSONNEL SERVICE

The Personnel Service column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of $2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a key number which will be carried for five additional insertions unless a discontinue order is received. Items pertaining to soil positions will be inserted one time in the *Soil Science Society of America Proceedings* unless otherwise specified. The following insertions, published in earlier issues, are still available: 4–1, 4–2, 4–3, 6–1, 7–1, 7–2, 7–3, 8–1.

—A—

POSITIONS WANTED

Soils and crops scientist, D.Sc. in Agr., with European degrees, graduate studies in U. S., 30 years of practice in Europe, U. S. and tropical and subtropical South America (teaching, research, land utilization, crop production, farm planning and operation), 65 major publications on own original research, seeks college-research or/and teaching position. Accepts comparatively low salary, having own means, merely aiming to devote his remaining years to promulgation of his knowledge derived from exceptionally extensive research work and broad experience. 9–1.

—A—

SOIL SCIENTIST, B.S. 1951, soil conservation and agronomy, M.S. degree, 1952, soil physics and agronomy, Ohio State Univ., seeks position in design, development, research or sales promotion, in soils, irrigation, or soil and water field with industry or public agency; willing to travel moderately. Limited farm experience, tool designer, 3 years; civil engineering, 2 years; soils mechanic, 4 months; soil physics research, 2 years; 1 year post-graduate study; age 32, no disability, married. Available on about 1 month's notice. Salary, open. 9–2.

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Microbiologist, Ph.D., wishes position with opportunity to do research. Research experience on symbiotic nitrogen fixing organisms, microflora of forage crops, and microbiology of grass silage. Also teaching experience. 9–3.

AGRONOMY JOURNAL

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Changes of address should be received by the 1st of the month in which they are to take effect.

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Articles concerned with instruction, demonstration, experimentation, or research in agronomy will be accepted for publication from members of the Society if deemed suitable by the Editorial Board. It is understood that articles submitted for publication have not appeared previously elsewhere and that they will not be offered for simultaneous publication in other journals without the consent of the Editor of the JOURNAL. At least one author of a paper must be an active member of the American Society of Agronomy.

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AGRONOMY JOURNAL

Volume 47 October 1955 Number 10

The Hills of Home[1]

G. G. Pohlman[2]

THE growth, development, and prosperity of our nation have resulted from the ingenuity of the people in making use of the store of natural resources bestowed so abundantly by nature. Each and every part of our nation has had a share in making it great.

Two years ago Myers (3) gave us an interesting account of the role played by the Great Plains in our development. Today, I should like to call to your attention some of the contributions from a part of the Appalachian area, that part where the sedimentary rocks are still exposed. This area is outlined in figure 1.

Millions of years ago, geologic erosion from a land mass to the east brought sediments into the area, which was then a shallow sea. Heat, pressure, and chemical reactions combined to cement the sedmients together into sandstones, shales, and limestones. Alternate deposition, uplift, folding, and erosion occurred over a period of several hundred years (figure 2).

During the early period of deposition (Cambrian Period), relatively simple forms of marine life constituted the principal life in the area. These became more abundant and complex with each new deposition. Plants adapted to land or shallow water appeared. During the latter part of the Paleozoic era, climax forests of Pteridophytes and Pteridosperms developed in the low-lying swampy area. Their partially decayed remains have given rise to the vast coal deposits found in the area.

A few million years ago the rocks were exposed permanently and the final stage of development of soils and topography was started. Then glaciers swept down from the north and covered much of the northern part of the region, leaving only remnants of the residual materials exposed. Unconsolidated sediments from the ocean were carried in to cover the southern part of the area leaving the central part exposed. The central part of the area is shown in figure 1.

At about the close of the Paleozoic or the beginning of the Mesozoic era, when the region was lifted above sea level for the last time, conditions became unfavorable for the marsh-loving flora and many of them disappeared. In their place came the newly evolved angiosperms from the south. Further uplift of the area caused these tropical species to migrate to the newly emerged coastal plain leaving only relict colonies in the Appalachians. Species from the north (arctotertiary forests) came down to take over as the principal forms. Changing climatic conditions, especially during the glacial periods, caused several migrations of vegetative types. At the end of the glacial age, the vegetation appears to have been stabilized with a dominant cover of hardwood types but with some conifers in parts of the region. This was the condition when our forefathers first visited the area.

The climate of the area, primarily classed as Continental, is strongly influenced by both latitude and elevation. The area has a range in latitude of somewhat more than 7°. Elevations range from about 250 to 5,000 feet above sea level. Growing season varies from about 130 to 200 days. Within a short distance, growing seasons may vary considerably because of elevation.

Rainfall varies from somewhat less than 30 inches to more than 60 inches a year, with low rainfall usually occurring east of the mountains and high rainfall at the high elevations in the mountains. On the average, rainfall is fairly uniformly distributed throughout the year but periods of summer drought of sufficient duration to affect plant growth often occur.

The hills and forests break the force of the wind to the extent that cyclones, tornadoes, and violent windstorms occur rarely. However, the hilly topography does encourage air movement so that sultry days without a breeze are rare.

SOILS

Under the relatively cool, humid climate and the native vegetation of chestnut, oak, pine, yellow poplar, and northeastern hardwoods and conifers, podzolization has been the dominant soil forming process. Podzols occur at the higher elevations in the northern part of the area. In areas where podzolization was less intense, brown podzolic, gray brown podzolic and red and yellow podzolic soils were formed. During soil development, the lime was soon leached from the sandstone and shales and even from the limestone parent materials. As a result, a large majority of the soils are strongly acid.

The hilly to steep topography of much of the area greatly influenced soil development. In some places, geo-

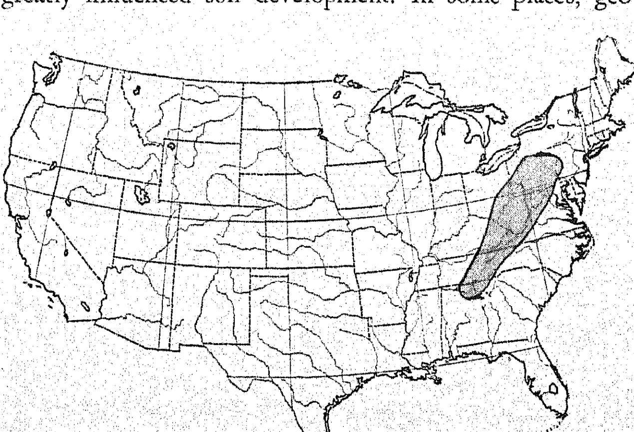

FIG. 1.—The area of non-glaciated Appalachian sedimentary rocks.

[1] Presidential address delivered before the American Society of Agronomy, Aug. 17, 1955, Davis, Calif.

[2] President, American Society of Agronomy and Head, Department of Agronomy and Genetics, West Virginia University, Morgantown, W. Va.

logic erosion kept pace with soil formation, and rocky pinnacles stretch upward toward the sky. On most of the hills, erosion limited the depth of soil and soil material. As a result, parent material strongly influences the soils. The parent materials were low in phosphorus and the resulting soils respond well to phosphate fertilizers. Potash in the parent material was quite variable. The supply in the soil is particularly low on the more level areas which have been most highly leached and which have also been heavily cropped. Other nutrients are usually not deficient in the type of farming practiced although magnesium, boron, molybdenum, and other deficiencies have been noted.

EROSION

Erosion is always a problem when man disturbs the natural cover of an area. Geologic erosion played a large part in shaping the hills and valleys. It is still taking place. Accelerated erosion, started in the clearings and burnings by Indians, speeded up as man increased the size of clearings to supply his needs. The soils, well supplied with organic matter from the luxuriant forests and having a favorable structure, absorbed water readily, and despite the cropping systems used on relatively steep hills, erosion was not immediately a serious problem. As continued tillage depleted both the organic matter supply and available nutrients and as the soil structure deteriorated, erosion became more serious. However, because of the nature of the soil and the parent material beneath it, it is recognized that more intensive use of sloping land is possible than in many areas. In the slope designations used, 3% is considered the maximum for A slope, 8 to 10% the maximum for B slope, and 15 to 20% the maximum for C slope. These are the slopes used for class 1, 2, and 3 land, respectively, provided all other conditions are favorable. Land for pasture may have a slope up to 30 to 40% depending on the soil.

On the relatively shallow soils, the loss of a few inches of soil is serious. But with proper attention to erosion control practices and with nature providing cover, if we cooperate, the land can be conserved for the future.

EARLY INHABITANTS

As far as can be determined, the Mound Builders were the first inhabitants of the area. Although their greatest concentration appears to have been in the upper Mississippi Valley, there are a number of mounds on the terraces along the Ohio River and its tributaries. One of the larger mounds, 900 feet in circumference and 70 feet high, is located at Moundsville, W. Va. The origin of the Mound Builders is veiled in mystery. It seems certain they came before the American Indian—but how long before is a matter of conjecture. The size of the mounds indicates that labor was plentiful. The presence of corn, beans, and

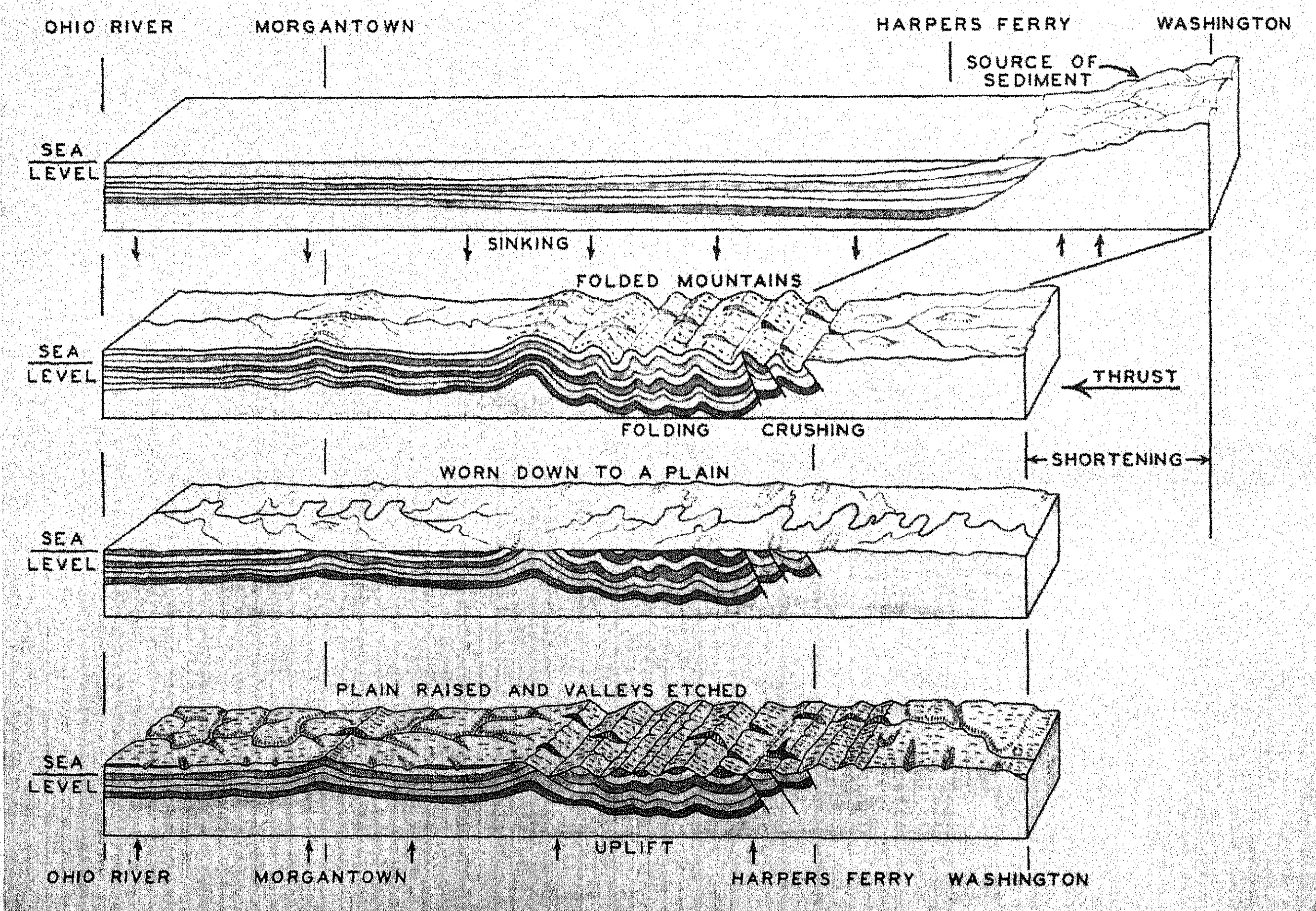

FIG. 2.—A sketch of the geological formation of the area. (Courtesy West Virginia Geological Survey).

other grains in the mounds shows at least a primitive type of agriculture, the first of which there is any record in the area.

The next evidence of occupancy was by the Indians. They may have followed the Mound Builders directly or there may have been an interval of unknown duration. For the most part, the Indians lived on the fringes of the area—the Iroquois in the north and the Mingoes and Delewares in the west. The mountainous area was nominally held by the Iroquois but was primarily used as a hunting and fishing area. There were almost no evidences of permanent settlements in the mountains. However, there is ample evidence of encampments and Indian trails through the area. The forest growth was so dense that food limited the supply of game. Burning seems to have been prevalent but was confined to small areas. Whether accidental or intentional, it provided openings for wild life food. As a result, the area was able to support a larger population of deer, buffalo, and other game. Burned areas were usually soon reforested but may account for the small accumulation of forest litter noted in some areas.

MINERAL RESOURCES

The West Virginia Geologic Survey lists 42 minerals and naturally occurring materials in West Virginia. Many of these occur in relatively small quantities and have not been utilized. A few of the more important ones in the area will be mentioned here.

Since its discovery in Pennsylvania about the middle of the eighteenth century, coal has played an important role in the economy of the Appalachian area and of the nation. Its easy access and good quality have made this the major coal producing area in the country. Approximately two thirds of the United States coal production comes from the Appalachians. Most of the coal comes from shallow mines. During World War I there was some strip mining. This was largely abandoned following the war but the need for coal and larger stripping machinery resulted in its revival on a larger scale during World II. Problems of land reclamation resulting from strip mining will be mentioned later.

William Penn reported the discovery of iron ore deposits in 1683. The first iron works began operation in 1716 in Berks County, Pa. Iron production moved westward and was reported in southwestern Pennsylvania in 1789. The charcoal iron furnaces contributed much to the nation's growth during the latter part of the 18th and first half of the 19th century. In fact, it was not until about 1880 that the Appalachian area lost its lead in iron production. Its importance is indicated by the statement made by Dodge (2) in 1865 that "the plows and automaton harvesters, which will hereafter garner the annual wealth of the western prairies, may be transported to all those plains in vessels fabricated by the labor of West Virginia from her oak and iron, and the metal of those implements may there be mined, the ore heated by the adjacent strata of coal, the requisite flux from the same hill, and all compacted into a perfect machine . . ." The machine has come true but the development of the iron ore deposits in the Lake Superior region, not then foreseen, altered the picture.

Oil seeps were known to the Indians and recognized by the early settlers before the beginning of the 19th century. The first oil was collected from the surface of a creek or pond. The history of the oil development in Pennsylvania is well known. From this it spread over much of the area and production reached its peak about 1891. Since then, production has declined but significant amounts of good quality oil are still being produced and drilling operations are still in progress.

Natural gas, associated with the oil deposits, was found by the early settlers in various parts of the area. Records of using gas in salt production date back to 1843. The supply served as the principal source for more than 50 years, when new deposits were found elsewhere. Production is still important, but the Appalachians no longer hold first rank in gas production.

Salt licks were common congregating places for buffalo, deer, and man. The Indians were using salt brine to make salt in the Kanawha Valley before 1753. Salt was being produced in the same area on a commercial scale in 1797 at the rate of 150 pounds per day. Early production was from salt springs. As the demand increased, men started digging for the source. Boring methods were crude at first. Credit for the development of drilling machinery later used in oil drilling goes to the Ruffner brothers who started drilling the first salt well in the Kanawha Valley in 1806. Salt production using modern methods is still important in the area.

The limestone and certain of the sandstones and shales are also used, and mineral waters are abundant, serving as centers for health and vacation resorts.

AGRICULTURAL DEVELOPMENT

Soon after settlements were made along the coastal area of the United States, hardy explorers moved westward to explore the new continent. Just how long it took to reach the mountains or who was the first white man to penetrate the Appalachian forests is not recorded. The top of the mountains was reached about 1670 and Fort Duquesne was established in 1754.

Settlement of the area was slow, considering its proximity to the east coast, and to the center of population then beginning to move westward. The mountainous terrain and rocky nature of some of the areas offered a greater challenge than following trails through the areas. Early settlements were made in some of the wider valleys and plateaus along the trails. Most of the settlers moved on westward despite additional danger from Indians as more distant outposts were reached. But with each migration a few stayed and spread out from the trails.

Undoubtedly there were about as many reasons for settling in the mountains as there were people settling. The rich forests, and clear rivers, and the beauty of the rugged terrain were undoubtedly factors, as well as the desire to settle down, which influences all of us at some time.

Pioneer settlers in any area are a hardy lot. Those in the Appalachian area were no exception. In a land covered with timber they hewed out first a plot of ground for their dwellings and then land for cropping. Clearing virgin timber for crops was a slow, laborious process with the methods then available. Forests were plentiful and wood was a surplus commodity in the area. As a result, much of the timber was wasted or poorly used. Log buildings and rail fences were the rule. Most of the log buildings are no longer evident but some of the fences are still maintained.

According to present standards the pioneers were self sufficient, as they have been in most areas. They produced most of the raw materials they needed, and sold or traded small surpluses for other necessities and luxuries. Living

was not particularly different from that in other new settlements except that the hills and mountains made tillage a little more difficult, but in return gave a sense of peace and security.

The type of clearing and the farm layout varied with topography. Where level bottomland was available, this was usually cleared first and the clearing continued partway up the hill. Where streams had not developed bottomland, clearings often started at the top of the hill and continued partway down the slope. Sometimes scattered clearings were made on benches on the hillside. In some cases clearings went from the top to the base of the slope.

Regardless of how the land was cleared for use, general practice was to produce crops for harvest for several years, then retire to pasture those acres which were most difficult to till. Some of the slopes used were too steep even for pasture but there was usually a plentiful supply of family labor and the virgin land produced good crops. With the range in soils and climate in the area, there was a wide range in crops, from buckwheat in the north to cotton in the south. But corn and small grains soon predominated. The corn was followed by a small grain, commonly wheat, and then hay or in some cases back to corn if more grain was wanted. The grains were used for human consumption as well as feed for the livestock—hogs, chickens, cattle, and sheep—which furnished some of the family necessities. The surpluses of grains and livestock and livestock products were marketed.

Although we do not think of the area as one of our major agricultural regions, farming was the principal occupation throughout most of the area. The hills with the residues from the forest were fertile, and the soil was easily tilled. Agricultural production increased as the forests were removed and the better lands planted to crops. The yields of corn and wheat, the principal grains, were good, usually slightly above the national average. Climate was favorable and droughts were less common than in the corn and wheat belts. And being near to the east coast and with the growing markets resulting from industrial expansion, marketing was a simple problem. Production figures show that both wheat and corn acreage increased up to about 1900.

Almost from the beginning, it was recognized that the land was well suited for grass and grazing. Land planted to timothy and clover soon became covered with bluegrass and furnished good pasture for livestock. Hogs which required grain became less important, and the farmers turned to cattle and sheep. Grain was grown primarily to supplement the grasses which grew so well. Hay production for winter feed supplanted some of the grains in the system and the production of livestock, beef cattle, dairy cattle, and sheep became the dominant type of farming.

In addition to the general picture of a developing livestock economy, certain other specialized types of farming developed in more or less local areas. It was general custom for each farm to set aside a plot for orchard, garden, and small fruit production. Many of the orchards have been long abandoned but in some areas orcharding developed into a major enterprise. Small fruits, buckwheat, cotton, sweet sorghums, and tobacco achieved local importance in scattered areas.

The development of industry based on the natural resources of coal, oil, and gas resulted in a considerable movement from the land to the cities. The competition from the newer, more level agricultural areas tended to reduce the importance of the agricultural production in the area. Erosion on the steeper slopes became more serious. As a result, the number of people depending on agriculture, the size of farms, and the acreage of crop land began to decrease about the beginning of the twentieth century. Even before this time, some of the leaders began to look for ways of improving income in rural areas. In 1839, Volume I, Number I of the "Silk Culturist and Farmer's Manual" was published at Bruceton Mills, W. Va. This publication gave directions on the growing of silk worms and mulberry trees. The silk industry never became established in the area but the effort shows an early attempt to introduce new crops and to improve living standards in the area.

During the depression years, there was a considerable migration from industry back to the farm. The number of farms increased as persons lost their jobs in industry and returned to eke out an existence on their native soil. During this time an experiment in resettlement was instituted by the federal government. The goal was to relocate unemployed persons so they could supply part of their subsistence by farming, and to develop industries which would furnish part-time employment. The relocated people did not know much about agriculture, and the development of industries was not as easily accomplished as it appeared to enthusiasts for the program. The homes are still occupied but in many instances by people who have elected rather than were selected for this type of living.

PROGRESS THROUGH RESEARCH

Progress results from the ability of people to explore the unknown and to make use of the discoveries made. The exploration of new frontiers of land and its resources has always intrigued man and has given us some names which have been renowned in history, fiction, and verse. George Washington surveyed much of the area. The exploits of Daniel Boone and Davy Crockett have made them legendary figures. The hardy pioneers who followed and settled the land, hewing out farms from forest and facing the dangers and problems of living in isolation must also be given credit for much vision and courage. In an age when the struggle for food and shelter took most of men's ingenuity, the pioneers were able to satisfy their own needs and provide some surpluses.

Each of the experiment stations in the states comprising the area has played and still is playing a part in improving the agriculture and the living standards of the rural people. I want to give you a glimpse of some of the research which has resulted in such improvement.

The first extensive longtime field experiments in the United States were laid out by Dr. W. H. Jordan in 1881 at what is now Pennsylvania State University. As we look at these experiments in the light of present experimental methods, they leave much to be desired. But they have served as source material for almost 100 publications, both technical and practical, and have served as a basis both for farm practice and for later experiments.

It is difficult to credit any one set of experiments with the discovery and proof of principles, but the Jordan plots have impressed, among other things, the following facts (4):

"*(1)* Lime alone, without fertilizers or manure, produces yields no better than where nothing had been applied.

(2) Fertilizers alone, on acid soils, give very poor re-

sponse. Lime can increase the efficiency of fertilizers up to 300% as measured by crop response.

(3) Phosphorus is the first limiting element of Pennsylvania soil. When used alone or in any combination, it has resulted in a substantial increase in yield.

(4) High yields can be maintained indefinitely with inorganic commercial fertilizers.

(5) Where manure was applied at 6, 8, and 10 tons per acre, the greatest return per ton of manure was obtained from the lightest application.

(6) Reinforcing manure with superphosphate is a sound and profitable farm practice."

These plots have also served as a source of soil of known, variable treatment which is needed in evaluating soils and soil treatment.

The courage and foresight of Dr. Jordan, in starting these plots, and of the many persons involved in managing and maintaining them in the face of increasing pressure is to be commended. The 75th anniversary of their founding was celebrated by the Northeastern Branch of the American Society of Agronomy at its meeting at the Pennsylvania State University on July 25 to 28, 1955.

The importance of grass in a hilly area, where for much of the land, pasture is the most intensive, desirable use, has not been overlooked. A. D. Hopkins started some of the earliest work on improvement of varieties of grasses in 1893. In 1908, Virginia started experiments on pasture management. Results were reported in 1914 (1). The importance then attached to the work is indicated by the fact that the bulletin is illustrated with colored pictures. It is also significant to note that the senior author of this bulletin, Lyman Carrier, was a charter member of the American Society of Agronomy and one of its vice presidents in 1913.

Kentucky 31 fescue has received much attention since it was first noted growing on a farm in eastern Kentucky in 1931 where it apparently had been growing for some 50 years. As with every other new crop, its use was greeted with success and failure but it has found a very useful place in our agriculture.

The recent emphasis on grassland farming and the forage improvement programs at the State Experiment Stations and the Regional U. S. Pasture Laboratory may be expected to further improve forage production.

The rapid rise in strip mining of coal during World War II with its attendant effect upon the landscape has attracted much interest. Following the stripping operation, the land was left extremely rough and unsightly. Frequently, in agricultural areas, additional land was made useless. Public sentiment was so strong that some positive action was deemed necessary. It was insisted by some that the original contour be restored. But, without immediate cover, erosion was serious and this method has been abandoned on the hills. The usual method now used on hillsides is to level a part of the area, leaving steep banks above and below the graded spoil. Where the stripping is on rolling land it is put back so machinery can be used. But even after the leveling is done, it was found that securing cover was still a problem. Some spoil can be limed, fertilized, and seeded and a good cover and fair crop of hay secured. Other spoil, which had considerable pyrite, produced so much sulfuric acid from its oxidation that damp spots appeared. These were found to be due to a high concentration of sulfuric acid. No growth could be secured in these spots. But nature, given time and the abundant rainfall of our climate, will remove the excess acid, and with proper treatment satisfactory cover can be secured. The effects of strip mining will long be evident but the bare, unsightly condition can be remedied, thanks to research (5).

The most important resource of any nation is its youth. Many programs have been organized to help train our young people into useful citizens. One of the most far reaching of these is the 4-H program associated with agricultural extension services throughout the country. This program has had a normal healthy growth with contributions from many individuals and areas. One important contribution to the conduct of the 4-H program came with the establishment of the first county 4-H camp in Randolph County, W. Va., in 1915. This was followed by the establishment of a state camp at Jackson's Mill, W. Va. Since its establishment, the idea of county and state centers of activity have spread to many other areas.

These are only a few of the more significant advances which have contributed to the agricultural welfare of the area and of our nation. To list all contributions would require much more time and space than is available. Grimes Golden and Golden Delicious apples, new varieties of forage, grain crops, fruits, vegetables, and other management practices for crops and soil, laboratory procedures, fertilizer practices, and many other research results could be added to those discussed above.

A LOOK TO THE FUTURE

The acreage of land under cultivation has been declining steadily since about 1935. The retirement of land not suited for cultivation, the encroachment of villages and cities, and industrial expansion have all played a part in this reduction of acreage. This decline may be expected to continue as these forces exert more pressure in the future.

In order to give a picture of the general nature of farms, I should like to report some census data for West Virginia, which I think is fairly typical of the area. According to the 1950 census, about one fourth of the farms were classed as commercial farms. The term, commercial farm, includes a wide range of conditions. Some of the farms in the relatively level limestone valleys have enough level land so that modern farming methods can be used. Farms along the larger streams may also have considerable level land. These areas are suited to almost any type of cropping system and may be expected to continue as commercial farms until the land is taken for urban or industrial expansion.

Farms in the smaller valleys or on rolling hilltops with less level land but some slopes suitable for strip cropping and with a larger acreage of more rolling land suitable for pasture may be expected to continue to contribute livestock and livestock products to our national economy. But some of the so-called commercial farms have none of these advantages. With relatively small acreages of land suited to machinery, they have been able, by using much hand labor, to provide a living for the farm family. Some of the more energetic in this group have turned to more intensive enterprises—broiler production, turkeys, small fruits, truck farming, and tobacco—and with good management have improved their living standards. Such a change in type of farming seems necessary if these farms are to continue to contribute to our national welfare.

Already some of these latter, less productive farms have become part-time farms where only a part of the living is earned from the farm. The 1950 census shows about one fourth of the farms were part-time farms. With increasing industrialization, this type of farm may be expected to continue. It provides a part of the living, it furnishes room in the great out of doors for raising a family, and it provides a cushion against future unemployment.

The remaining farms are classed as rural residences. These contribute little in the way of farm products but do provide a residence away from the crowded cities—a situation which many people enjoy.

The picture of classes of farms may give a somewhat erroneous picture of land use. Although commercial farms only represent 25% of the total number, they include more than half of the land in farms and produce about 85% of the value of products sold.

The vast expanses of virgin timber which greeted the eye of the early explorers and settlers are gone. They were exploited to make room for farms and cities and to provide lumber for a growing nation. At first the forests near water transportation fell; then as more timber was needed, railroads, built at first to carry coal, spread through the hills and mountains to remove the timber. As was the case in most of our early history, the supply seemed inexhaustible as sawmills, large and small, spread over the area. Valuable timber was wasted because of fire and misuse. But much of the land was too steep, rocky, or inaccessible for other uses, so what remained of the forest cover spread to recover the hills. With our present emphasis on conservation and with the improved forest management methods which are being employed, it is reasonable to expect the Appalachian area to furnish more forest products for our nation.

Water, a resource which is causing us much concern as a nation, is normally supplied by nature in abundance. Early used as a means of transportation, it was natural that our cities grew near the major streams. And although used now in much larger quantities, and sometimes polluted by mine water and industrial wastes, there is still a sufficient supply to attract new industries. Conservation on the land, farm ponds, and larger reservoirs are slowing down the runoff to maintain a more uniform flow. In more remote areas, the beaver is cutting down trees and building dams and ponds which help regulate the flow. All of these are giving clearer streams which will provide more bass, trout, and other fish to lure the fisherman into one of the many paradises of nature. Farther downstream, there is more water for home and industrial use and for navigation. In spite of what has been or is being done, the water supply, both from the standpoint of quantity and quality, needs additional attention if an adequate supply is to be maintained.

With the combination of farms and forests, hills and valleys, one cannot overlook some of nature's other bounties. The combination of cleared land and forest makes conditions favorable for a variety of game, the most abundant of which is deer, a creature of beauty and the hunter's delight.

Nature provided flowering trees and shrubs—the dogwood, redbud, service berry, azalea, rhododendron, laurel and many others. Beautiful in their natural surroundings, they are also being used to beautify our homes. For those with a more practical turn of mind, there are cranberries, blueberries, blackberries, and others which may be had for the taking and which may be found useful in developing new strains or varieties for the market. Holly, too, grows naturally and furnishes beauty for the holiday season. In the mountains, the sugar maple shares its life blood each spring to make our table more inviting.

But even without these special gifts of nature, the hills and changing seasons provide beauty as we pass from winter to spring to summer to fall.

These are some of the contributions of the Appalachian area—natural resources of water, coal, oil, gas, salt, and timber; agricultural resources of land, crops, and livestock; wild life resources of fish and game; scenic resources of hills and valleys, flowers and seasons; and finally a people who appreciate these resources and use them to help keep America strong.

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Associations of Morphological Characters and Earliness in Oats[1]

W. M. Ross[2]

BASIC studies of earliness in the oat plant are a prerequisite to a proper understanding of inheritance of the character. Though earliness in a variety is measured usually by date of heading, time of bloom, date of ripening, or some other means at the end of the growing period, it actually is determined fairly early in the development of the plant. More adequate knowledge at the early stages should be helpful in interpreting the character at the later stages.

In grasses the growth period, from planting to anthesis, is divided into two distinct phases, one vegetative and the other reproductive. In the first phase, after germination and after emergence, the plant remains short with unelongated internodes, leaves grow, new leaves are initiated, and tillers are formed while the growing point remains smooth and rounded though it may elongate slightly.

In the second phase the growing point differentiates, and small ridges and bumps appear on its surface that eventually form structures of the inflorescence. This transition is called floral differentiation or initiation. At the same time the inflorescence and its parts are being produced, internodes elongate, leaves grow, and a noticeable increase in height occurs. Rate of growth and development during the growth phases in relation to heading and to certain morphological characteristics of the plant will be discussed in this paper. Though several experimental lines were studied along with standard varieties, the term variety will be used to refer to any individual one.

LITERATURE REVIEW

As early as 1914, Harlan (5) recognized in barley a division of the growth period into phases which he classified as the period from germination to jointing, the period of heading, and the period of maturity. The nature of the first two in wheat were elaborated upon by Kiesselbach and Sprague (9). Bonnett (1, 2, 3) then described in detail these growth periods in his morphological studies on oats, wheat, and barley.

Hahn[3] dissected the shoots of growing oat plants at successively later stages of development. He found that differences in the degree of development of the growing points in 5 oat varieties at 34 days was closely related to differences in the time of heading.

In inbred lines of corn, Leng (10) found certain patterns of development which were inherited in the F_1. Within a line, the number of leaves externally visible gave a fairly good indication of the rate of internal development; but between lines, a wide range of leaf numbers was found at the time of tassel initiation. He found that a delay in planting shortened both growth periods, but the period from planting to tassel initiation was shortened proportionately more than the period from initiation to anthesis.

The importance of the length of the photoperiod and temperature in determining length of growth phases in plants was stressed by McKinney and Sando (12). McKinney (11) pointed out that relative earliness should be studied under different environmental conditions to determine the factors composing the earliness character.

Quinby and Karper (13) showed that duration of vegetative growth in sorghum was determined by the time of floral initiation, making the study of maturity actually a study of the genes influencing biochemical changes which bring about floral initiation. Delay of initiation in sorghum resulted in a large number of leaves and internodes. An association also was found in sorghum between tall height and lateness.

A number of investigators, adequately cited by Sappenfield (14), studied the inheritance of earliness in oats, but none associated the expression of earliness or lateness with anything except heading or ripening. Only Immer and Stevenson (8) correlated heading data and plant height in oat crosses.

Hayes *et al.* (6) found a low positive correlation between height and heading in winter wheat, while Bridgeford and Hayes (4) found a high negative correlation in spring wheat. Alim[4], working with wheat, reported a low positive correlation between height and heading and a low negative correlation between heading and tiller number; all were non-significant. Rosenquist[5] found a positive correlation between tiller number and lateness in wheat.

Only McKinney and Sando (12) pointed out that earliness is associated with reduced internode number in wheat, but no literature reviewed showed a similar relationship in oats.

METHODS

Fourteen oat varieties ranging over 20 days difference in maturity from early to late were studied at the Illinois Agricultural Experiment Station in 1950 and 1951. From previous observations and records Ill. 43–271, 60 Day, Fort, Ill. P137, Ill. 39–47, Columbia, and Ill. 30–2088 had been classified as early; Clinton, Valor, Marion, and Gopher as early to midseason; and Segetal, Victory, and Golden Giant as late. Dates of planting were April 15, 1950 and April 20, 1951. All seeds were space planted 8 inches in paired plots composed of 2 rod-rows each with rows 1 foot apart.

In 1950 samples of 6 to 8 plants were taken every 3 days from one of a paired plot of each variety and dissected to study shoot development. Near the time of panicle initiation, extra samples were taken to determine accurately that date. Heading data were taken from the other plot of the pair, this date being taken as emergence of the upper spikelets from about three-fourths

[1] Contribution from the Department of Agronomy, Illinois Agr. Exp. Sta. Published with approval of the director of the station. A portion of the data from a thesis submitted in partial fulfillment of the requirements for the Ph.D. degree. Presented to the annual meeting of the American Society of Agronomy, Cincinnati, Ohio, Nov. 17–21, 1952. Received April 16, 1955.

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Table 1.—Days to panicle initiation, days from initiation to heading, and days to heading of 14 oat varieties, Urbana, Ill. 1950–51.

Kind	Days to panicle initiation			Days—initiation to heading			Days to heading		
	1950	1951	Av.	1950	1951	Av.	1950	1951	Av.
Ill. 43–271	30.0	23.8	26.9	33.0	32.0	32.5	63.0	55.8	59.4
60 Day	32.0	23.5	27.8	32.0	33.8	32.9	64.0	57.2	60.6
Fort	32.0	23.0	27.5	33.0	33.5	33.2	65.0	56.5	60.7
Ill. P137	33.0	22.5	27.8	32.0	34.2	33.1	65.0	56.8	60.9
Ill. 39–47	31.0	23.0	27.0	34.0	33.8	33.9	65.0	56.8	60.9
Columbia	30.0	24.0	27.0	34.0	34.0	34.0	64.0	58.0	61.0
Ill. 30–2088	30.0	24.0	27.0	36.0	32.2	34.1	66.0	56.2	61.1
Clinton	31.0	24.5	27.8	33.0	34.0	33.5	64.0	58.5	61.2
Valor	31.0	24.5	27.8	34.0	34.5	34.2	65.0	59.0	62.0
Marion	32.0	24.5	28.2	33.0	34.5	33.8	65.0	59.0	62.0
Gopher	36.0	24.8	30.4	31.0	33.7	32.4	67.0	58.5	62.7
Segetal	38.0	30.2	34.1	43.0	41.6	42.3	81.0	71.8	76.4
Victory	36.0	30.2	33.1	47.0	42.0	44.5	83.0	72.2	77.6
Golden Giant	38.0	30.0	34.0	49.0	47.0	48.0	87.0	77.0	82.0
Average	32.9	25.2	29.0	36.0	35.9	36.0	68.9	61.0	65.0
L.S.D. 5% level	—	1.4	1.1	—	2.2	3.2	—	1.3	2.4

of the plants. From 25 random plants, measurements were made on height, and tillers and internodes were counted.

In 1951 the same procedure was followed except that four replications of paired plots were used. In addition to the above data, detailed measurements were taken of the length of each internode and of the length of the panicle. Rate of leaf development was studied by counting the number of leaves visible at successively more advanced stages of growth. Height measurements and internode counts were made both years on the main stalk of the plant which was assumed to be the tallest culm.

Simple correlations were made each year among the various characters studied to assist in interpreting the relation of one to another and to the expression of maturity in the various varieties studied. For the 2-year period, characters were compared by either the "t" test or the analysis of variance.

RESULTS AND DISCUSSION

Just as there are differences in date of heading among varieties, there also are differences in date of panicle initiation which are indicated by data in the column, "days to panicle initiation," in table 1. In 1950 the period from planting to panicle initiation ranged from 30 to 38 days, a difference of 8. In 1951 the range was 22.5 to 30.2, a difference of 7.7. With allowances for experimental error and significant differences, a given variety generally responded the same each year, though days from planting to panicle intiation were significantly less in 1951 than 1950.

A wider range was found in days from planting to heading in the 2 years studied. The ranges were 63 to 87 days in 1950 and 55.8 to 77.0 in 1951, differences of 24 and 21.2, respectively. In both years, Ill. 43–271 was earliest and Golden Giant latest. As indicated by the "t" test, days from planting to heading were significantly less in 1951 than in 1950.

It is important to note that average days from panicle initiation to heading, on the other hand, were not significantly different in the 2 years. Ranges were from 31 to 49 days in 1950 and from 32 to 47 in 1951. Averages were nearly identical, 35.9 and 36.0 days respectively. Allowing for 5 days difference in planting time and differences in weather conditions for the 2 years, the same variety generally required the same period of time for development in the period from panicle initiation to heading while the length of the vegetative period, planting to panicle initiation, differed markedly.

Table 2.—Number of head-bearing culms on 14 oat varieties.

Kind	Number head-bearing culms		
	1950	1951	Av.
Ill. 43–271	6.0	13.6	9.8
60 Day	6.5	15.6	11.0
Fort	6.3	15.3	10.8
Ill. P137	5.8	14.7	10.2
Ill. 39–47	7.2	15.9	11.6
Columbia	7.7	15.8	11.8
Ill. 30–2088	6.1	12.4	9.2
Clinton	4.2	11.4	7.8
Valor	5.2	16.4	10.8
Marion	6.7	12.4	9.6
Gopher	8.2	22.2	15.2
Segetal	9.4	16.9	13.2
Victory	7.4	9.4	8.4
Golden Giant	6.6	16.0	11.3
Average	6.7	14.9	10.8
L.S.D. 5% level	—	—	NS

Since it appears that length of day and temperature are the principal factors determining floral induction, relative earliness cannot be expressed accurately without these specific environmental requirements regardless of the genetic factors involved. Also when dealing with unknown material it is desirable to test under more than one environmental condition to find these specific conditions so that maturity characters will not be masked.

Other characters were measured and are reported in tables 2, 3, and 4. Only number of head-bearing culms (table 2) showed irregularity for the 2 years. Plant height (table 3), on the other hand, tended to show a similar pattern for each of the years, but the relationship between height and earliness was inconsistent.

Internode number (table 4) was one of the characters least affected by environment. There were no significant

differences between the 2 years in the number of internodes produced by any variety regardless of differences in days required to heading, plant height, or other characters. Early varieties had fewer internodes than the late varieties. This observation corresponds with the observations of McKinney and Sando (12) on wheat, Quinby and Karper (13) on sorghum, and statements by Harlan (5) indicating the relationship in barley.

Because there was so little variability in internode number in 1950, rate of leaf development, which corresponds to rate of node development, was studied in 1951 to see if it could be used as an index of plant maturity. From periodic leaf counts, given in table 4, it is found that there was little difference among varieties in the number of visible leaves on a given calendar date. This indicates that all of the varieties probably started growth with the same number of embryonic leaves. Though this has not been reported previously in oats, Hubbard and Leng (9) found several inbred lines of corn to have the same number of leaves in their embryos.

Number of visible leaves at panicle intiation was more informative. A clear relationship existed between leaf number and time of panicle initiation. Early varieties had few leaves visible and the late ones relatively more at panicle initiation. In all varieties, one or two more leaves had been initiated than were externally visible at the time of panicle initiation. In all but the three latest varieties, practically all of the leaves were unfolded from the whorl 30 days after planting. Number of leaves, number of nodes, and number of internodes were the same, and any lack of correspondence in the data between number of leaves and number of internodes can be accounted for by the difficulty of counting internodes in mature plants because of density near the crown.

Correlation coefficients were calculated to determine the degree of relationship among certain of the plant characteristics studied, and are reported in table 5. Highly significant correlations of +0.822 and +0.969 for 1950 and 1951, respectively, were found between days to heading and days from planting to panicle initiation, indicating that one is as good a measure of earliness as the other. Days to panicle initiation may well be the more accurate measure, but it is not determined so readily as date of heading.

There were significant correlations of +0.917 and +0.928 in 1950 and 1951, respectively, between the number of internodes and days to heading, later varieties having more internodes than early ones. The rate of leaf initiation apparently is the same in oats regardless of maturity, thus a delay in panicle initiation results in more leaves being initiated. Hence, more internodes must develop before heading can occur in the late varieties.

Similarly, the correlation of days to panicle initiation and internode number were +0.833 and +0.946. The highest correlation of any factors studied was that of internodes at maturity and number of leaves at panicle initiation which was a highly significant +0.976 in 1951. These correlations are readily explained on the basis of the interrelation of leaf number and internode number and by the cessation of leaf initiation at the time of panicle initiation.

Plant height and head-bearing culms were both significantly correlated with heading and panicle initiation in 1950 but not 1951. Because height has the components-internode number, internode length, and panicle length, detailed study was made of these factors in 1951. Measurements were made in each internode of each variety, and few or no differences were found with the exception of the first internode beneath the head, the peduncle. Because of increasingly shorter internodes down the stem, only the peduncle, second, and third internodes can have much influence on height.

It was found that the peduncle was significantly shorter in the late varieties, and that there were negative correlations of –0.843 and –0.849 between peduncle length and days to heading and number of internodes at maturity, respectively. Late varieties which have more internodes than early varieties also have shorter peduncles, perhaps owing to some kind of intraplant competition among the internodes. The peduncle, being the longest internode, is the most readily affected. Much of the variation in height among varieties also can be attributed to panicle length which appeared to have no relation to earliness or lateness.

Table 3.—Height, peduncle length, and panicle length of 14 oat varieties.

Kind	Plant height—ins.			Peduncle length 1951—ins.	Panicle length 1951—ins.
	1950	1951	Av.		
Ill. 43–271	35.4	44.4	39.9	16.4	10.5
60 Day	35.1	39.6	37.4	17.0	10.6
Fort	34.6	40.2	37.4	18.1	8.7
Ill. P137	32.6	40.1	36.4	16.6	10.1
Ill. 39–47	31.4	44.2	37.8	18.4	10.8
Columbia	35.2	42.2	38.7	17.0	10.6
Ill. 30–2088	34.0	40.8	37.4	16.3	9.4
Clinton	30.4	40.1	35.2	15.1	9.0
Valor	30.3	40.2	35.0	15.8	9.6
Marion	32.5	40.3	36.4	17.2	9.9
Gopher	32.3	41.0	36.6	16.0	9.0
Segetal	37.1	41.2	39.2	12.5	10.2
Victory	38.3	42.8	40.6	13.6	10.8
Golden Giant	39.2	49.0	44.1	13.8	17.2
Average	34.1	41.9	38.0	15.9	10.5
L.S.D. 5% level	—	—	3.8	—	—

Table 4.—Internode and leaf number of 14 oat varieties.

Kind	Internodes at maturity			Leaf no.		
	1950	1951	Av.	24 days	30 days	Initiation
Ill. 43–271	5.0	5.4	5.2	3.8	5.4	3.8
60 Day	4.9	4.8	4.8	3.8	5.6	3.6
Fort	4.9	4.8	4.8	3.8	5.4	3.5
Ill. P137	4.7	4.7	4.7	4.0	5.6	3.6
Ill. 39–47	4.2	5.0	4.6	3.4	5.3	3.1
Columbia	4.9	5.0	5.0	3.8	5.4	3.8
Ill. 30–208	4.6	5.2	4.9	3.6	5.4	3.6
Clinton	4.6	5.5	5.0	3.8	5.4	3.9
Valor	4.1	5.0	4.6	3.8	5.4	3.9
Marion	4.7	5.1	4.9	3.7	5.6	3.8
Gopher	5.1	6.0	5.6	3.7	5.0	3.9
Segetal	6.1	6.6	6.4	3.4	5.0	5.0
Victory	6.2	7.0	6.6	3.8	5.2	5.2
Golden Giant	6.9	7.4	7.2	3.7	5.2	5.2
Average	5.0	5.5	5.3	3.7	5.4	4.0
L.S.D. 5% level	—	—	0.5	0.3	0.2	0.3

Table 5.—Correlations among plant characters in relation to earliness in 14 varieties of oats.

Correlation	Value of r	
	1950	1951
Days to panicle initiation and days to heading	+0.822**	+0.969**
Days to panicle initiation and number of internodes	+0.833**	+0.946**
Days to panicle initiation and height	+0.586*	+0.470
Days to panicle initiation and number of leaves at panicle initiation	—	+0.976**
Days to panicle initiation and number of culms	+0.576*	−0.103
Days to heading and height	+0.771**	+0.265
Days to heading and number of internodes	+0.917**	+0.928**
Days to heading and number of leaves at panicle initiation	—	+0.954**
Days to heading and number of culms	+0.477	−0.078
Days to heading and length of peduncle	—	−0.843**
Number of internodes and height	+0.899**	+0.609
Number of internodes and number of culms	+0.512	−0.021
Number of internodes and number of leaves at panicle initiation	—	+0.928**
Number of internodes and length of peduncle	—	−0.849**
Height and number of culms	+0.489	+0.522
Height and number of leaves at panicle initiation	—	+0.466
Height and length of peduncle	—	−0.333
Number of culms and number of leaves at panicle initiation	—	−0.136

* Significant at 5% level.
** Significant at 1% level.

A concurrent study of the inheritance of earliness among a number of crosses involving varieties considered herein was made at the same time that detailed studies were conducted on the parents. Conventional methods of studying segregation for heading date were used. On the whole, inheritance studies were unsuccessful in arriving at exact methods of selecting plants of definite maturities or for determining the number of genetic factors involved. The primary reasons for not obtaining definite information from the inheritance studies are believed to be *(1)* that the populations were to small for such a complex quantitative character and *(2)* a lack of basic information on the expression of earliness in standard varieties.

From these results panicle initiation obviously is one of the most accurate methods for determining earliness in the oat plant. It can be used best for pure lines and F_1's but may be used also for relatively early generation segregating material such as F_3 and F_4. Because days to panicle initiation is so highly correlated with certain other plant characters, such as internode number and peduncle length, these might satisfactorily be used in its place.

Hence, it is proposed that future inheritance studies of earliness in oats, and perhaps other small grains, involve not only a study of segregation for heading date, but also that detailed information be taken on the plants for peduncle length and internode number. With severe environments masking or influencing one character, information on three will allow greater breeding progress, particularly when populations are small.

SUMMARY AND CONCLUSIONS

1. Two years' data on fourteen oat varieties and lines revealed time of panicle initiation to be as good a measure of earliness as time of heading.

2. Days to panicle initiation and days to heading were decreased by later planting in 1951 than in 1950 with the vegetative period appearing to be more sensitive to environmental conditions than the reproductive period.

3. Days from panicle initiation to heading remained constant for both years in spite of different planting dates and weather conditions, indicating need of specific photoperiods and temperature for floral initiation and a specific time for elaboration of the floral structures.

4. Rate of leaf development was nearly identical among all varieties throughout early growth, but leaf numbers at time of panicle initiation were markedly lower for early varieties and higher for later ones.

5. Internode number was the least variable morphological character studied and the most closely related to earliness, early varieties having low internode numbers and late varieties high numbers.

6. Though head-bearing culms and plant height were strongly influenced by environment, the length of the first internode or peduncle was significantly shorter in early varieties; panicle length was influential in determining total plant height.

7. For earliness inheritance studies and in practical oat breeding programs for selecting lines of definite maturities, these findings suggest the study of individual plants of the segregating population for not only date of heading, but internode number and peduncle length. Information on these three characters should result in more accurate classification and in more effective selection by eliminating some of the environmental influence and, perhaps, allow use of somewhat smaller populations.

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The Restoration of Fertility to Cytoplasmic Male-Sterile Corn[1]

John R. Edwardson[2]

IN THE production of hybrid corn, detasseling can be completely avoided through the use of cytoplasmic male-sterile seed parents in both single crosses and a fertility-restoring inbred as the pollen parent of the pollinator single cross. In the grower's field, such a double cross would be expected to produce a ratio of 1 fertile:1 sterile plant, or the grower's field can be rendered completely pollen fertile by including 2 fertility-restoring inbreds in the pollinator single cross, producing seed of this cross through hand detasseling of one of the component inbreds. In either system, success is dependent upon the use of genes which effectively restore fertility to cytoplasmic male-sterile corn.

U. S. inbreds are being tested at many state experiment stations for genes which restore fertility to lines exhibiting various types of cytoplasmic male-sterility; but since the majority of U. S. inbreds lack fertility-restoring genes, it is desirable to find other sources of fertility-restoring genes. One such source is to be found among Latin American maize varieties.

MATERIALS AND METHODS

The male-sterile lines utilized in this study were Tx203Ms developed by Dr. J. S. Rogers of the Texas Agricultural Experiment Station and C106Ms derived from Tx203Ms by Dr. D. F. Jones of the Connecticut Agricultural Experiment Station. C106Ms was used as the female parent in all crosses by Latin American varieties. Dr. P. C. Mangelsdorf, of the Botanical Museum, Harvard University, generously made available to the writer his collection of Mexican, Central, and South American maize varieties for testing for fertility-restoring genes.

The three phenotypes *sterile, partially sterile,* and *fertile* described by Rogers and Edwardson (7) were used to determine the mode of inheritance of the male-sterile character. A few plants classified as *trace* in the field were considered extreme expressions of the partially sterile phenotype. If some trace plants were overlooked in classification, they were classified as sterile. From 3 to 12 anthers were exerted by plants classified as trace, and they contained some viable pollen. This viability was demonstrated by the production of a few seed on sterile and fertile plants after they had been pollinated with crushed anthers from trace plants.

In fitting data from segregating populations to all ratios, partially sterile, trace, and sterile plants were grouped and treated as sterile. This was done on the assumption that partially sterile and trace phenotypes are the product of the interaction of modifying genes and/or environmental factors with the male-sterile genotype. If the F_1 generation of the test cross C106Ms × Latin American variety was male-sterile, the variety tested was considered to be homozygous for sterility-inducing genes *msms;* if the F_1 generation was male-fertile, the variety tested was considered to be homozygous for dominant fertility-restoring genes *MsMs;* and if the F_1 generation segregated sterile and fertile plants, the variety tested was considered to be heterozygous for dominant fertility-restoring genes *Msms.*

Races of Maize in Mexico (9) contains chromosome knob counts for several Mexican varieties. A comparison of these knob counts with degree of fertility found in the F_1 generation of crosses of C106Ms × Mexican varieties indicated a correlation between high degree of fertility and high knob number. Paxson and Mangelsdorf's[3] list of knob counts for Latin American varieties also provided a source of information for such comparisons. In addition to the published lists of knob numbers, knob number was estimated for varieties of Peruvian, Ecuadorian, and Bolivian corn using the root tip technique of Morgan (4).

Mangelsdorf's multiple tester stocks produced completely sterile F_1 generations when crossed on C106Ms. In order to test for linkage of fertility-restoring genes and non-marker alleles of the various marker genes contained in the multiple tester stocks, the following crosses were made: Tx203Ms × 127C produced a completely fertile F_1 generation; (Tx203Ms × 127C)F_1 × multiple tester produced progeny segregating fertile and sterile plants in a 1:1 ratio. The offspring of selfed, fertile plants in this progeny would be expected to segregate fertile and sterile plants in a 3:1 ratio and normal and recessive marker characters in a similar ratio. The data from classification of fertile, sterile, marker, and normal characters were tested for goodness of fit to a dihybrid 9:3:3:1 ratio. If no significant deviations from the 9:3:3:1 ratios were obtained, it was assumed that there was no linkage between fertility-restoring genes and the marker gene involved, or that the deviation from independent inheritance was not great enough to be detected in the population grown. Markers on chromosomes 1, 2, 4, 6, 7, 8, 9, and 10 were tested for linkage with the fertility-restoring locus.

The detection of differences in the cytoplasm of C106Ms and C106 was attempted by two methods: cytological investigation and chromatography. In the cytological investigations, Erliki's fluid was used as a fixative. All fixed material—endosperm, embryo, root tip, leaf parenchyma, pollen mother cells, and pollen of C106Ms and C106—was stained with Heidenhain's hematoxylin. Leaf epidermis and P.M.C.'s were stained with Janus Green B. and root tips and P.M.C.'s were stained with neo-tetrazolium chloride.

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[3] Maize News Letter, 1953.

Table 1.*—Summary of classification of U. S. inbreds and Latin American varieties for fertility restoring genes.

(A) F_1's of Texas cytoplasmic sterile × U. S. inbreds†							
			Segregating				
F	P	C	P/C	P/C/F	P/F	C/F	Total
25 7.71%	31 9.56%	236 72.83%	23 7.09%	5 1.54%	3 0.92%	1 0.35%	324
(B) F_1's of Texas cytoplasmic sterile × Latin American varieties							
17 13.71%	1 0.10%	41 33.10%	8 6.50%	24 19.40%	5 4.03%	28 22.60%	124

* Abbreviations used in tables 1, 2, 3, and 4 are:
F = Male-Fertile Plants
P = Partially Sterile Plants
C = Completely Sterile Plants
ms = C106Ms, which is inbred Conn. C106 containing the cytoplasmic male-sterile character.
† Compiled from Regional Corn Improvement Conference Reports (1950–1954).

In order to obtain material for testing with chromatographs, young tassels from C106 and C106Ms were collected and stored in a deep-freeze. Before freezing, P.M.C.s from five spikelets taken from the mid-portion of the main axis of the tassel were fixed in 3:1 alcohol:acetic acid, later stained with aceto-carmine, and examined for meiotic stages. Tassels were selected for chromatographic comparisons only when they appeared to be in a comparable stage of development; that is, when both tassels contained pollen mother cells within the same range of meiotic stages.

Filtered homogenates of these selected tassels from C106 and C106Ms were subjected to differential centrifugation to obtain fractions of the homogenates, with one containing chiefly plastids and the other chiefly mitochondria (Stafford (8) and Price[4]). Chromatographic separation by capillary ascent of portions of homogenates, not centrifuged, which were either applied directly or as ether extracts to strips of Whatman No. 1 filter paper, as well as centrifuged fractions containing *(1)* chiefly mitochondria and *(2)* chiefly plastids, was accomplished with the following solvents: *(a)* n-butanol, water and glacial acetic acid in a ratio of 4:5:1; *(b)* iso-propanol, water, and 28% ammonia in a ratio of 10:1:1; *(c)* methanol, n-butanol, benzine, and water in a ratio of 5:4:2:2. Two groups of separating substances were studied; flourescent materials revealed by ultra-violet light and ninhydrin-positive materials revealed by spraying the chromatograms with a 0.2% solution of ninhydrin in ethyl alcohol.

RESULTS AND DISCUSSION

Test for Fertility-Restoring Genes

A total of 124 Mexican, Central, and South American varieties were crossed on C106Ms in order to test these varieties for fertility-restoring genes. Of the 124 F_1 populations resulting from these crosses, 96 were classified in both 1951 and 1952. In only one F_1 population was there a significant difference in classification between the 2 years, probably due to sampling errors in planting seed. Seventeen (13.71%) of the varieties tested produced completely fertile F_1 generations. For the purpose of studying the inheritance of the nuclear genes which interact with the specific cytoplasm to produce the male-sterile character, these 17 varieties were assumed to be homozygous for fertility-restoring genes. Fifty-seven varieties (45.96%) produced F_1 generations segregating fertile plants as well as sterile and/or partially sterile plants. These 57 varieties were assumed to be heterozygous for fertility-restoring genes. One variety (0.10%) produced an F_1 generation which contained all partially sterile plants. The fertility controlling genes of this variety, Eduador 1672, are discussed later under "Modification of the Male-Sterile Character." Forty-nine varieties (39.5%) produced F_1 generations which were completely male-sterile, or segregated partially male-sterile and male-sterile plants. These 49 varieties were assumed to be homozygous recessive for sterility-inducing genes. Of all varieties tested, it was found that 59.6% contained fertility-restoring genes. These results differ quite sharply from the results obtained from tests of U. S. inbreds, since they indicate that these exotic maize varieties provide an excellent source of fertility-restoring genes. (See tables 1 and 2).

[4] Price, C. A. Respiratory enzymes and the growth of seedlings. Unpublished Ph.D. dissertation, Department of Biology, Harvard University, Cambridge, Mass. 1952.

Table 2.—Summary of classification of F_1's of C106Ms × Latin American varieties 1951–1952.

Variety	F	F/P	F/C	F/P/C	P	P/C	C	Total
Mexico	5	1	3	2	0	3	6	20
Guatemala	1	0	4	2	0	0	4	11
Honduras	1	0	1	5	0	1	1	9
Nicaragua	0	0	2	2	0	0	0	4
Costa Rica	1	1	1	0	0	0	2	5
Salvador	1	0	0	0	0	0	0	1
Panama	1	0	0	0	0	0	0	1
Colombia	2	0	6	3	0	1	8	20
Venezuela	0	1	1	0	0	0	2	4
Brazil	1	0	0	1	0	0	2	4
Ecuador	0	1	1	0	1	1	3	7
Peru	2	1	7	5	0	0	9	24
Bolivia	2	0	2	2	0	2	2	10
Paraguay	0	0	0	1	0	0	0	1
Uruguay	0	0	0	0	0	0	1	1
Argentina	0	0	0	1	0	0	1	2
Totals	17	5	28	24	1	8	41	124

Inheritance of the Male-Sterile Character

All the Latin American varieties tested are open pollinated varieties, and therefore could contain fertility-restoring and sterility-inducing genes[5]. Since single plant selections from these varieties were tested, all of those selections producing male-sterile F_1 populations could have been taken

[5] Little, Jones, and Clarke (3) report that over 86% of the onion varieties tested contained both the *Ms* gene which restores fertility and the *ms* gene which induces sterility in cytoplasmic male-sterile onions.

from varieties containing *msms*, *Msms* and *MsMs* genotypes. Therefore the percentages found of Latin American varieties containing fertility-restoring genes are probably underestimates of the actual percentages.

In segregating F_1 populations a ratio of 1 fertile:1 sterile plant would be expected if the male-sterile character were controlled by 1 gene interacting with the cytoplasm of C106Ms. But 2 genes can also produce 1:1 ratios in F_1 populations as well as other types of segregation. While most segregating F_1 populations fit a 1:1 ratio, some populations fit other assumed ratios (1:3, 3:1, 5:3, and 3:5 fertile:sterile plants). All the segregating F_1 populations were too small, however, to provide valid tests for goodness of fit to these ratios. On the other hand, the segregation of fertile and sterile plants in F_2 and backcross populations can provide information which permits testing the assumptions that the male-sterile character is controlled by one or more pairs of alleles.

Individual plant selections from 13 of the 17 completely fertile F_1 populations were crossed and the offspring classified. Each of the 23 F_2 populations fit an assumed ratio of 3 fertile:1 sterile plants. (See table 3). Individual plant selections from completely fertile F_1 populations were crossed on C106Ms, and the backcross generations were classified. All 13 backcross populations fit an assumed ratio of 1 fertile:1 sterile plants. (See table 4). The results of classifying F_2 and backcross generations indicate in every

Table 3.—Test of goodness of fit to 3:1 and 13:3 ratios, fertile:sterile plants, in 23 F_2 populations.

Cross	Number of plants					P values	
	F	Sterile			Total	13:3	3:1
		P	C	Total			
1. (ms × Mex. 1794) × (ms × Mex. 1792)	195	2	56	58	253	0.07	0.46
2. (ms × Mex. 1794) × (ms × Mex. 1727)	222	24	43	67	289	.06	.48
3. (ms × Hond. 1267) × (ms × Mex. 1733)	136	3	37	40	176	.21	.54
4. (ms × Mex. 1794) × (ms × Hond. 1267)	31	0	14	14	45	.05	.44
5. (ms × Col. 1428A) × (ms × Mex. 1733)	111	1	39	40	151	.01–.02	.74
6. (ms × Col. 1360) × (ms × Mex. 1792)	98	3	26	29	127	.28	.66
7. (ms × Brazil 1698) × (ms × Mex. 1733)	130	0	43	43	173	.04	.98
8. (ms × Mex. 1794) × (ms × Brazil 1698)	178	2	55	57	235	.03	.80
9. (ms × Mex. 1794) × (ms × Peru 1306)	98	2	35	37	135	.01–.02	.46
10. (ms × Peru 1307) × (ms × Mex. 1733)	84	0	32	32	116	<.01	.60
11. (ms × Peru 1307) × (ms × Mex. 1794)	105	9	36	45	150	<.01	.19
12. (ms × Bol. 1499) × (ms × Mex. 1733)	177	1	57	58	235	.01–.02	.94
13. (ms × Bol. 1506A) × (ms × Mex. 1794)	49	3	9	12	61	.92	.44
14. (ms × Bol. 1506A) × (ms × Col. 1428A)	40	1	19	20	60	<.01	.18
15. (ms × Bol. 1506A) × (ms × Col. 1360)	95	2	33	35	130	.03	.68
16. (ms × Bol. 1506A) × (ms × Bol. 1499)	222	1	78	79	301	<.01	.64
17. (ms × Bol. 1506A) × (ms × Hond. 1267)	146	5	40	45	191	.88	.71
18. (ms × Bol. 1506A) × (ms × Brazil 1698)	76	0	29	29	105	.03	.62
19. (ms × Bol. 1506A) × (ms × C.R. 1051)	151	0	60	60	211	<.01	.25
20. (ms × Col. 1428A) × (ms × Brazil 1698)	44	1	20	21	65	<.01	.22
21. (ms × Col. 1428A) × (ms × Hond. 1267)	125	5	30	35	160	.36	.42
22. (ms × Brazil 1698) × (ms × Hond. 1267)	55	1	14	15	70	.66	.58
23. (ms × Bol. 1506A) × (ms × Bol. 1506A)	185	15	48	63	248	<.01	.88
Totals	2,753	81	853	934	3,687		

Table 4.—Test of goodness of fit to 1:1 ratio, fertile:sterile plants, in 13 backcross populations.

Cross	Number of plants					P value 1:1
	F	Sterile			Total	
		P	C	Total		
1. ms × (ms × Mex. 1794)	77	0	58	58	135	0.12
2. ms × (ms × Mex. 1794)	174	0	164	164	338	.60
3. ms × (ms × Mex. 1733)	125	0	114	114	239	.48
4. ms × (ms × Hond. 1267)	18	0	18	18	36	.99
5. ms × (ms × C.R. 1051)	125	0	116	116	241	.56
6. ms × (ms × Col. 1428A)	81	1	92	93	174	.42
7. ms × (ms × Brazil 1698)	82	0	74	74	156	.54
8. ms × (ms × Peru 1307)	185	52	114	166	351	.31
9. ms × (ms × Peru 1306)	178	48	114	162	340	.40
10. ms × (ms × Bol. 1506A)	80	13	81	94	174	.32
11. ms × (ms × Bol. 1499)	211	1	218	219	430	.70
12. ms × (ms × Bol. 1499)	71	0	79	79	150	.58
13. ms × (ms × Bol. 1516*)	64	0	51	51	115	.26
Totals	1,471	115	1,293	1,408	2,879	

* Fertile plant selected from segregating F_1 population.

cross tested that one pair of alleles controls the production of the male-sterile character.

While all F_2 populations fit an assumed 3:1 ratio, there were 9 populations which also fit an assumed ratio of 13:3. Whether apparent 13:3 segregations are produced by chance deviations from 3:1 ratios in the direction of slightly increased numbers of fertile plants, or by the action of two factors could be determined only by progeny tests. Such tests have not been made; however, if two factors are involved, their detection would be expected during the conversion of normal inbreds to the male-sterile condition. Inbreds of the genotype $ms_1\ ms_1\ ms_2\ ms_2$ would be expected to produce completely male-sterile F_1 generations when crossed on C106Ms and the first backcross generations would be expected to segregate 1:1 fertile:sterile plants. Such a condition has not been found but its occurrence would confirm an hypothesis that two factors with dominant and recessive epistasis control fertility restoration.

Modification of the Male-Sterile Character

While the percentage of partially sterile plants in all F_1 generations of C106Ms × Latin American varieties grown in 1951 and 1952 were 11% and 9% respectively, 10 of these F_1 generations contained partially sterile plants in 1951 and no partially sterile plants in 1952. These results might be due to sampling errors since small samples from the same F_1 seed were grown both years. Another interpretation could be that the environmental conditions in 1951 induced the modification of the sterile condition to the partially sterile condition in these 10 genotypes, while in 1952 under different conditions the male-sterile condition remained stable. That environmental factors influence the expression of the male-sterile character is indicated by information in Regional Corn Conference Reports from 1950–54. Sixteen F_1's of U. S. inbreds × Texas cytoplasmic male-sterile produced sterile, partially sterile, fertile, or combinations of these phenotypes at different locations.

In addition to variation in degree of fertility at different locations, there may be variations within a plant. Although the great majority of tillers had the same phenotype as the main stalk, among the progeny of nine different crosses, tillers were observed whose phenotype was not the same as that of the main stalk. In the progeny of seven crosses, sterile tillers were produced by partially sterile or fertile main stalks. However, in the F_1 generation of the cross C106Ms × Mexico 1073, 2 sterile plants occurred, each with 1 partially sterile tiller; while in the F_1 generation of the cross C106Ms × Peru 1487A, 2 fertile tillers were produced by 1 sterile main stalk. The occurrence of tillers of a phenotype different from that of the main stalk could be considered as a chimera according to the particle distribution hypothesis of Gabelman (1).

Ecuador 1672 when crossed on C106Ms produced F_1 generations in 1951 and 1952 which contained only partially sterile plants. If Ecuador 1672 is homozygous for a gene producing partial sterility which is an allele of the fertility-restoring gene, then one-fourth of the offspring of crosses of the type (ms × fertility restorer) × (ms × Ecuador 1672) and reciprocal would be expected to be partially sterile. Partially sterile plants occurred in populations produced by each of five such crosses but not in the expected proportion. In the five populations resulting from such crosses, the percentages of partially sterile plants were 4, 4, 13, 17, and 20.

The partially sterile plants occurring in these five populations are probably the result of the action of modifying genes from Ecuador 1672 which influence the male-sterile genotype to produce some viable pollen. Modifying genes with similar effects on male-sterile characters have been reported by von Wettstein (10) in flax and by Owen (5) in sugar beets.

Relation of Fertility Restoration to Chromosome-Knob Number

Among 35 varieties producing completely sterile or segregating partially sterile and sterile F_1 generations, the average knob number was found to be 3.9. Among 42 varieties producing completely fertile or segregating fertile and sterile F_1 generations, the average knob number was found to be 5.6. The correlation coefficient r was calculated by the variable squared method and was found to be 0.37 and t was found to be 3.441. The null hypothesis that there was no correlation between knob number and fertility was discarded when a P value of less than 0.01 was obtained.

Several varieties, chiefly from Peru, Ecuador, and Bolivia, which produced either completely fertile or segregating fertile F_1 generations had no knobs. This would suggest that chromosome knobs *per se* have no influence on fertility restoration. The simplest explanation for the correlation between knobs and fertility seems to be that the frequency of fertility-restoring factors is somewhat higher in varieties with high knob number than in those with low knob numbers. This does not necessarily imply a causal relationship although it is possible that such a relationship does, in fact, exist.

Location of Fertility-Restoring Genes

The P values obtained from χ^2 tests of goodness of fit to the 9:3:3:1 ratio for fertility-restoring, sterility-inducing, normal, and marker genes ranged from 0.05 to 0.89 with no significant deviation being found. The segregation of *Gl* on chromosome 7 and fertility shows deviations from independent assortment (P = 0.05) and the deviations are in the direction of linkage (coupling phase): *GlMs* 178; *Glms* 45; *glMs* 48; *glms* 27.

The χ^2 test for goodness of fit to the 9:3:3:1 ratio was separated into components in which one degree of freedom tests discrepancies in the segregation *Gl*:*gl* ($\chi^2 = 0.004$, P = 0.95): one tests discrepancies in the segregation *Ms*:*ms* ($\chi^2 = 0.111$, P = 0.74): and one degree tests the linkage between the two pairs of factors ($\chi^2 = 7.529$, P = <0.01). The *Gl*:*gl* and *Ms*:*ms* components show good fits to the assumed 3:1 ratios, and the linkage component χ^2 is highly significant indicating linkage between *Gl* and *Ms*.

Using Fisher's product method for calculating linkage and tables provided by Immer (2), the recombination percentage between *Gl* and *Ms* was found to be 39.1 ± 2.5%. A χ^2 test for goodness of fit to the observed frequencies of phenotypes assuming 39.1% recombination between *Gl* and *Ms* yields a probability value of 0.89.

Additional data are needed to verify the indication that the fertility-restoring gene is located on chromosome 7: in the linkage tests only a small population was classified (298); F_2 data were used; chromosomes 3 and 5 were not tested; and the marker locus on any of the chromosomes tested which seem to show independent inheritance with fertility may not have been close enough to the fertility-restoring gene to permit separation of parental and crossover types into classes showing sufficient numerical differences in order to rule out independent assortment.

Sterility-Inducing Components of the Cytoplasm

Rhoades (6), in discussing cytoplasmic male-sterility in *Iojap* maize, states that mutated mitochondria might induce the male-sterile condition. In neither sectioned material nor material stained with neo-tetrazolium could any morphological or numerical difference in mitochondria be detected between C106 and C106Ms. The extremely small size and large number of the entities involved could easily account for a failure to detect any differences. The absence of detectable morphological or numerical differences in mitochondria does not prove that mitochondria are not involved in cytoplasmic male-sterility since there may well be a disturbance in their function which is not reflected in their size, shape, or number. Meiosis was observed to be normal in both lines, and no cytoplasmic differences were detected during the study of meiosis.

No consistent differences between C106 and C106Ms were found when portions of fractions containing chiefly plastids or portions containing chiefly mitochondria from tassels of the two lines were applied directly or when ether extracts of these fractions were applied to the paper.

Ether extracts of filtered homogenates, not centrifuged, from entire tassels of C106 and C106Ms did show differences in fluorescent and ninhydrin-positive materials. Although these differences were not consistently repeatable, they were of this nature: either a fluorescent, or more frequently a ninhydrin-positive material, occurred in the chromatogram of C106Ms while no corresponding material was detected in the chromatogram of C106.

The number of chromatograms, 40, is too small to permit any definite conclusions to be drawn from the results obtained. However, the results indicate that C106Ms tassels possess a ninhydrin-positive material after division I of meiosis which is not present in C106 tassels. The occurrence of ninhydrin-positive materials strongly indicates that an amino acid or acids are present in the male-sterile tassels at a stage of development in which they are absent in male-fertile tassels.

SUMMARY

Genes which restore fertility to cytoplasmic male-sterile maize were found to occur in 59.6% of Latin American maize varieties tested. The frequency in U. S. inbreds of such genes has been found by other workers to be 10.5%.

The results of classifying 23 F_2 populations and 13 $backcross_1$ populations from crosses of cytoplasmic male-sterile × Latin American varieties indicates that a single pair of genes (*Msms* or *MsMs*) is responsible for fertility-restoration. However, there is a possibility, but not a very great probability, that the segregation in some of the F_2 populations is the consequence of hybridizing F_1 plants which carry two different genes for fertility restoration.

The male-sterile character can be influenced by unidentified environmental conditions in such a manner as to cause the production of some viable pollen. A modification of the male-sterile character, probably involving change in internal environment rather than in external conditions, was observed occasionally in plants whose main stalk and tillers were of different phenotypes in regard to the male-sterile character. Ecuador 1672 probably contains several genes which modify the interaction of *ms* with "sterile" cytoplasm to produce partial sterility.

Chromosome knobs were found to have no influence on the male-sterile character. Linkage tests involving the *Ms* gene and genes on 8 of the 10 chromosomes of a multiple tester show a slight indication of linkage of *Ms* with *Gl* on chromosome 7. A recombination percent of 39.1 was obtained.

No difference between cytoplasmic male-sterile inbreds Tx203Ms and C106Ms, and their male-fertile counterparts Tx203 and C106, were found in meiosis or in chromosome number. No differences between C106Ms and C106 were found in the size, shape or number of mitochondria.

Results from a small number of paper chromatographs indicate that male-sterile tassels may contain an amino acid or acids at a stage of development in which they are absent in male-fertile tassels.

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Some Effects of an Anionic Sodium Sulfonate Type Surfactant upon Plant Growth[1]

E. C. Spurrier and J. A. Jackobs[2]

SURFACE active agents, or surfactants, are being used in the manufacture and processing of commercial fertilizers to improve the blending of materials and to speed up the manufacturing process. This use of surfactants in fertilizer has stimulated an interest in the effects of these additives on seeds and growing plants. Observations on pasture fertility demonstration plots have indicated that the dry matter and protein yields from these plots may have been increased by the use of a surfactant in the fertilizer[3]. On the basis of these observations, research work was initiated to study the effects of these materials, if any, upon the efficiency of the use of nitrogen by forage grasses, and to determine the effect of a surfactant, in various concentrations, upon seed germination and plant growth. In addition, the effect of a surfactant upon water movement in a soil was observed.

REVIEW OF LITERATURE

There is very little information in the literature concerning the use of surfactants in fertilizers and their effect upon plant growth. Seymour[3] has theorized that the addition of a small amount of surfactant to a nutrient medium should reduce the upward movement of mobile ions in soil due to capillary movement of water. If this is true, then the mobile forms of nitrogen will not move to the soil surface where they will be unavailable to the plant in dry weather. Seymour also presented data from pasture plots which showed that both the yield of dry matter and the nitrogen content of the forage were higher for the plots receiving a mixed fertilizer containing a surfactant than for the plots treated with straight materials without a surfactant.

METHODS AND MATERIALS

The experiments reported here were conducted with Santomerse No. 1, a surfactant consisting of 40% active anionic alkyl aryl sulfonate type surfactant and approximately 60% sodium sulphate. The active ingredient is essentially the sodium salt of dodecyl benzene sulfonic acid. The rates of surfactant used in these experiments were based on the total ingredients in the compound rather than on the basis of the 40% active ingredients.

The term surfactant as used in this paper refers to Santomerse No. 1 unless otherwise stated.

In 1953, a field experiment was conducted to determine the effects of Santomerse No. 1 upon the efficiency of the use of nitrogen by bluegrass on a Sidell silt loam soil. The following fertilizers were applied:

1. 10–10–10[4] commercially prepared with Santomerse No. 1
2. 15–15–15 manually mixed without Santomerse No. 1
3. 0–25–25 manually mixed with Santomerse No. 1
4. 0–25–25 manually mixed without Santomerse No. 1

The surfactant was added at the rate of 5 pounds per ton of fertilizer, which is the reported rate used in commercial processing. Two rates of application were made: 36 and 156 pounds per acre each of N, P_2O_5, and K_2O. One-half of the plots were treated on Oct. 14, 1953, and the other half were treated on March 25, 1954. The 16 treatments were arranged in a randomized block design with 4 replications. The plot size was 6 feet by 20 feet. The herbage from a 20-foot strip, 34 inches wide and cut at 1½ inches above the soil surface was used for dry weight determinations. Sub-samples of the harvested herbage were saved for nitrogen analysis.

A greenhouse study was conducted to observe the effects of 6 levels of Santomerse No. 1 ranging from 0 to 100 ppm. and 5 levels of nitrogen ranging from 0 to 135 ppm. on the growth of perennial ryegrass. All possible combinations of the various levels of surfactant and nitrogen were used. Superphosphate, KCl, and minor elements were mixed thoroughly to 1,500 g. of silt loam in 6-inch clay pots. Ten ryegrass seedlings were transplanted into the pots of treated soil to ensure uniform plant populations. The test pots were placed in shallow pans to which water was added. Periodically the pots received water as a surface application. The herbage was harvested four times. After the fourth harvest, using one replication of the potted ryegrass as a check, additional increments of 30 ppm. and 60 ppm. of nitrogen were added to the second and third replications, respectively, to observe the response of the ryegrass to the additional nitrogen. All harvested herbage was dried, weighed, and analyzed for nitrogen.

Evaporation studies were conducted to determine the effect of Santomerse No. 1 upon water movement in a soil and the ultimate rate of water evaporation from a soil surface. Six tubes of sand, 3 treated with 100 ppm. of surfactant and 3 untreated, were mounted on ringstands. Tubes of sand were used in this experiment, due to inability to secure consistent results when using soil in the evaporation apparatus. Each tube was connected to an enclosed water supply system in which the exact amount of water evaporation from the respective tubes could be measured.

A study was made to determine the concentration at which surfactants begin to be detrimental to plant growth. Red clover (*Trifolium pratense* L.) and Sudangrass (*Sorghum vulgare* var. *sudanense* L.), as test crops, were seeded in pots of silt loam soil to which a surfactant was added at 7 different levels from 0 ppm. to 100,000 ppm. Two surfactants, Santomerse No. 1 and O & C 60[5], were compared in the study. The surfactant was added to the soil in aqueous solutions up to levels of 100 ppm. At higher levels, the dry powder form was added. In all cases, the soil and surfactant were mixed thoroughly before seeding or transplanting the test crop.

The rate of water absorption by wheat and soybeans was determined by submerging seeds in tap water and tap water plus 100 ppm. of Santomerse No. 1. Seeds were also soaked for 24 hours in solutions of surfactant varying from 0 ppm. to 10,000 ppm. The seeds were then removed from the respective solutions, blotted to remove free water, and weighed.

Germination studies involved the placement of wheat and alfalfa seeds, embryo down, on blotters thoroughly soaked with solutions of varying concentrations of Santomerse No. 1 in petri dishes. The petri dishes were then placed in a germinator maintained at 18° C. until all viable seeds had sprouted. The blotters were kept moist by adding the appropriate solution.

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[3] Seymour, J. L. Recent advances in the use of surfactants in the manufacture of superphosphate and mixed fertilizers. Paper presented at the American Farm Research Association meeting, Terre Haute, Ind., Oct. 19, 1953.

[4] 10–10–10 for the fall applications and 12–12–12 for the spring applications.

[5] A sodium type surfactant prepared by the Oil and Chemicals Products Co., Inc. of New York, N. Y.

EXPERIMENTAL RESULTS

An analysis of variance of the data secured from plots of Kentucky bluegrass which had received various treatments of fertilizer with and without nitrogen and surfactant indicated that differences in yields of dry matter and protein content of the herbage were a response to nitrogen fertilizer. There were no significant differences in either dry matter production or protein content resulting from the presence of surfactant in the fertilizer applied. The nitrogen × surfactant interaction was not significant.

The herbage yields of bluegrass with respect to nitrogen, surfactant, and date of application are presented in table 1.

Table 1.—The herbage yields of Kentucky bluegrass with nitrogen, surfactant, and date of application as variables at Urbana, Ill.

Comparison	Tons of dry matter per acre	Significance of difference
Nitrogen vs. none	1.842 vs. 0.986	**
Surfactant vs. none	1.387 vs. 1.441	N.S.
Fall vs. spring	1.449 vs. 1.379	N.S.

** P <.01.

The protein content of the herbage is shown in table 2. Protein percentages were increased by the nitrogen applied and the protein content of the herbage from the plots receiving the spring applications of nitrogen was significantly higher than that from the fall-treated plots.

Table 2.—Protein content of herbage of Kentucky bluegrass with nitrogen, surfactant, and date of application as variables at Urbana, Ill.

Comparison	Average % protein in herbage	Significance of difference
Nitrogen vs. none	16.4 vs. 12.5	**
Surfactant vs. none	14.5 vs. 14.4	N.S.
Fall vs. spring	13.6 vs. 15.3	**

** P <0.01.

Differential responses of dry matter to the treatment combinations of applied N and PK are shown in table 3.

There was no indication of a differential response to N or to PK due to the presence of surfactant in the fertilizer, either in terms of dry matter production or protein content.

Following the first harvest of the bluegrass, a severe burning was observed on many of the plots that had received the higher rate of nitrogen. The plots were rated according to the degree of burning observed. Results of the rating indicated that the plots receiving the higher rate of nitrogen in the fall with surfactant showed less burn than those plots without surfactant.

In the greenhouse studies where potted ryegrass was used as a test crop, the effect of different rates of surfactant and nitrogen fertilizer on dry matter production and protein content was compared. There were highly significant differences in yields of dry matter due to the rate of nitrogen applied, but the response to surfactant was not significant. The yields of the ryegrass herbage are given in table 4.

Table 3.—Differences in herbage production of Kentucky bluegrass when treatments were applied in combination on Agronomy South Farm, Urbana, Illinois.

Comparison	Tons dry matter per acre	Difference tons DM/A*
Difference due to N:		
With surfactant and without surfactant	0.733—0.978	0.245
In fall and in spring	0.961—0.750	0.211
Response to PK:		
With surfactant and without surfactant	1.021—0.952	0.069
In fall and in spring	0.969—1.004	0.035

* No significant differences.

Nitrogen content in the herbage from the various treatments did not differ significantly.

After the fourth harvest when the ryegrass showed symptoms of a nitrogen deficiency, additional nitrogen was applied to the pots to determine if the surfactant already present in the soil would affect the response to nitrogen fertilizer. There was a highly significant response to added nitrogen in terms of dry matter yields and protein content but no effect was observed from the presence of the surfactant in the soil.

While the ryegrass experiment was in progress, it was observed that the soil surface in some of the pots was dry while others were moist. The pots were watered from the bottom and water moved up in the pot by capillarity. It appeared that something was interfering with the movement of water in some of the pots. Three evaluators scored the pots independently prior to each harvest according to the degree of surface moisture present. Upon analysis of the scored values, it was determined that the pots of soil which had received the high rate (100 ppm.) of surfactant were significantly drier than were the other pots in the series.

Having observed the above soil moisture responses to surfactant, separate soil-water evaporation studies were conducted to determine the effect of a surfactant upon the rate of water movement in the soil. The data from an experiment conducted with sand are presented in table 5.

Less water was evaporated from the surface of the columns of sand treated with surfactant than from columns of sand without surfactant, indicating that the addition of surfactant did affect the movement of water within the

Table 4.—Yields of ryegrass herbage with varying rates of nitrogen and surfactant (grams of dry matter per plot).

Nitrogen		Surfactant	
Treatment	g./pot	Treatment	g./pot
0 ppm.	5.135	0.00 ppm.	5.148
5 ppm.	4.792	0.01 ppm.	5.208
15 ppm.	5.316	0.1 ppm.	5.072
45 ppm.	5.088	1.0 ppm.	5.232
135 ppm.	5.928**	10.0 ppm.	5.632
		100.0 ppm.	5.212

** Difference between 5.928 and check is highly significant.
CV (coefficient of variability) = 19.7.

Table 5.—The effect of a surfactant upon amounts of water evaporated from columns of sand* (ml. of H_2O per tube per day).

Air undisturbed		Air disturbed†	
Treatment	Ml. of H_2O evaporated per tube per day	Treatment	Ml. of H_2O evaporated per tube per day
No surfactant	13.92	No surfactant	36.4
Surfactant (100 ppm)	12.68	Surfactant (100 ppm)	24.4

† An electric fan was used to force air over the tubes of sand.
* Size distribution of sand particles —>1 mm., 28.9%; 0.5—1 mm., 48.6%; 0.25—0.5 mm., 19.3%; 0.1—0.25 mm., 3.0%; <0.1 mm., 0.2%.

columns and, consequently, reduced the amount of water available for evaporation from its exposed surface.

Results from the ryegrass experiment indicate that there was no apparent detrimental effect upon the grass when utilizing a surfactant in concentrations up to 100 ppm. in the soil. A study was conducted to determine the effect of surfactants on plant growth when used in greater concentrations. Two test crops, Sudangrass and red clover, were grown in soil treated with two surfactants, Santomerse No. 1 and O & C 60, at 7 rates. The average dry weights of the harvested herbage from the Sudangrass and red clover are presented in table 6.

Table 6.—Average dry weight of Sudangrass and red clover herbage grown in soil treated with two surfactants (ave. g. per pot per harvest).

Material	Treatment (ppm.)	Sudangrass g./pot	Red clover g./pot
Santomerse No. 1	0	5.457	3.520
	1	5.844	3.782
	10	6.093	3.592
	100	4.617	3.796
	1,000	3.351**	0.972**
	10,000	0.000	0.000
	100,000	0.000	0.000
O & C 60	0	5.457	3.520
	1	5.580	3.634
	10	5.955	3.714
	100	5.796	3.530
	1,000	3.051**	0.862**
	10,000	0.000	0.000
	100,000	0.000	0.000

** Difference from check highly significant
C.V.—12.6%.

There were no significant differences in yields of herbage of the grass or legume at 1, 10, and 100 ppm. concentration of surfactant, but there was a highly significant reduction in the yield of herbage of both grass and legume when 1,000 ppm. of surfactant were used. The low yield of the red clover at the 1,000 ppm. rate can be explained, in part at least, by relatively poor germination and emergence. At rates of 10,000 ppm. and above, germination was inhibited.

The data in table 7 show that the rate of water absorption into the seeds of wheat and soybeans was not increased by the addition of surfactant to the solution in which they were soaked.

The data on the rate of water absorption by wheat and soybean seeds are presented in table 8.

Table 7.—The weight (in grams) of water absorbed by 50 g. of wheat and soybean seeds after exposure to water and water plus surfactant for varying lengths of time.

	Hours in solution			
	6	12	18	24
Wheat:				
Surfactant (100 ppm.)	20.55	24.52	27.21	29.28
No surfactant	20.89	24.98	27.03	29.59
Soybeans:				
Surfactant (100 ppm.)	24.29	26.91	29.78	31.69
No surfactant	24.21	27.03	29.65	31.73

Table 8.—The effect of different concentrations of surfactant upon water absorption into wheat and soybean seeds. (g. of H_2O absorbed in 24 hours).

	Rates of surfactant					
	0	1	10	100	1,000	10,000
Wheat	29.08	29.64	29.62	29.58	27.98	26.18
Soybeans	31.58	31.59	30.97	31.12	29.90	29.22

High concentrations of surfactant had a slight depressing effect on total amounts of water absorbed into the seed. At rates up to 100 ppm., there was no apparent difference in amounts of water absorbed when the seeds were soaked for 24 hours.

The data in table 9 indicate that seed germination also was affected by high concentrations of surfactant. Legume seeds appear to be affected by lower rates of surfactant than are grass seeds. However, at low rates, there was no effect on germination by the incorporation of the surfactant into the germinating medium.

DISCUSSION

Results obtained in the field and greenhouse investigations failed to show that certain forage grasses utilize nitrogen more efficiently, as reported by Seymour[6], when a surfactant, Santomerse No. 1, was applied in the fertilizer. However, the surfactant did appear to have an effect upon water movement in the soil. Less water evaporated from tubes of sand containing 100 ppm. of Santomerse No. 1

[6] *Op. cit.*

Table 9.—The effect of different concentrations of a surfactant upon the germination of wheat and alfalfa seeds.

Seed	Rates of surfactant					
	0	1	10	100	1,000	10,000
Wheat						
% germination	98.0	96.0	99.0	99.0	100.0	46.0
% short sprouts*	2.0	2.0	2.0	2.6	6.6	48.7
Alfalfa						
% germination	91.0	89.5	88.3	87.0	77.3	45.6
% short sprouts*	0.33	1.2	1.9	1.9	8.2	26.3

* Sprouts less than 5 mm. in length.

than from the untreated tubes of sand. This indicates that the capillary movement of water in the sand was reduced by the surfactant. This is in agreement with Seymour's theory that capillarity is reduced by the addition of a surfactant to a soil medium.

The ryegrass study indicated that the movement of water in a soil is affected by rates of surfactant too low to affect plant growth. Data from the toxicity study showed that Sudangrass and red clover, grown in soil receiving various rates of surfactant, were not visibly affected until a concentration of over 100 ppm. was used. However, it was not possible to determine from this expermient whether the decrease in plant growth at the high rates was due to the active surfactant itself or to the sodium sulfate in the compound.

Seed germination was not appreciably affected until the concentrations of surfactant were increased above 100 ppm. The legume seed had less tolerance to the surfactant than the grass seed. There was no evidence that Santomerse No. 1, at the rates used in the processing of commercial fertilizer (3 pounds per ton of fertilizer), has any beneficial or detrimental effects upon plant growth. However, the possibility that surfactants may accumulate in the soil from repeated applications of fertilizer until there is an effect on the physical properties of the soil and plant growth cannot be disregarded.

SUMMARY

Surfactants are being used in the processing of commercial fertilizers. Because of this use, field and greenhouse studies were conducted to determine their effect, if any, upon the efficiency of the use of nitrogen by forage plants and upon seed germination and plant growth. Soil water relationships were observed.

Fertilizers with and without surfactant were applied on a Kentucky bluegrass sod. The response to nitrogen was not increased by the addition of surfactant to the fertilizer. However, there was less burning from a high rate of nitrogen fertilizer application where the surfactant was added.

Ryegrass was grown in soil receiving various amounts of surfactant and nitrogen to study the effect of a surfactant over a wide range of concentrations on dry matter yields and protein content of the harvested herbage. Under the conditions of the experiment, there was a highly significant response in yields of dry matter and protein to nitrogen, but no apparent response to the various levels of applied surfactants.

The addition of a surfactant to soil affects water movement and reduces the amount of water available for evaporation from a soil surface. It is possible to incorporate sufficient quantities of surfactant into a soil to affect its physical properties without injuring the plant.

Germination of certain crop seeds and emergence of seedlings was affected by the addition of surfactant into the soil at rates of 1,000 ppm., but there was no apparent effect at lower rates up to 100 ppm.

Yields of dry matter were reduced when Sudangrass and red clover were grown in soil containing 1,000 ppm. of surfactant; however, the reduction in yield may be due to the sodium sulfate in the compound rather than to the active ingredients of the surfactant.

Santomerse No. 1, when used at low rates in fertilizer processing, has no particular beneficial or detrimental effects upon seed germination or plant growth.

The Effects of Outcrossing on Forage and Seed Yields in Sericea Lespedeza, *L. cuneata*[1]

E. D. Donnelly[2]

SERICEA lespedeza, *L. cuneata,* is a perennial legume grown widely in the Southeast for hay and grazing. There are over one-half million acres of this crop in Alabama alone. It produces forage during the hot, dry summer months on eroded soils that are low in fertility, and there are no major diseases that limit its production or reduce its persistence. However, it is comparatively low in nutritive value and palatability. There are possibilities for improving these characteristics through plant breeding. Relatively little breeding work had been done with sericea; and, before the most effective breeding method for improving this crop can be determined, the effects of inbreeding and outcrossing must be known.

This study was conducted to determine whether there are increases in forage and seed yields from hybrid seed of sericea and, if so, the magnitude of the increases.

REVIEW OF LITERATURE

Sericea produces both apetalous and petaliferous flowers[3] The apetalous flowers are cleistogamous and the petaliferous are chasmogamous. All apetalous flowers are naturally self-pollinated, and petaliferous flowers may be naturally either self- or cross-pollinated[4] Stitt,[4] using procumbent growth habit as a genetic marker, found that 70.4% of the seed from petaliferous flowers resulted from cross-pollinations. McKee and Hyland[3] found that seed from the two kinds of flowers produced by sericea can be differentiated on the basis of pod shape. They observed that seed from the two types of flowers produced similar plants. However, in *L. latissima* the plants were quite dissimilar in amount and manner of growth. Plants from seed of apetalous flowers were much smaller and more prostrate than those from petaliferous flowers. Cursory observations made by Stitt[4] revealed no variation in size or vigor between the mother plant and selfed or open-pollinated generations of sericea.

McKee and Hyland[3] found that the percentage of the two flower forms varied from year to year depending on the environment. Sericea produced 75% of the seed from petaliferous flowers in 1939 and only 31% in 1940. They associated short days and low light intensity with the formation of apetalous flowers. Hanson[5] found this association in *L. stipulacea* and obtained predominantly apetalous flowers at 70° F.

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[3] McKee, R., and Hyland, H. L. Apetalous and petaliferous flowers in lespedeza. Jour. Amer. Soc. Agron. 33:811–815. 1941.

[4] Stitt, R. E. Natural crossing and segregation in sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. Jour. Amer. Soc. Agron. 38:1–5. 1946.

[5] Hanson, Clarence H. Cleistogamy and the development of the embryo sac in *Lespedeza stipulacea.* Jour. Agr. Res. 67:265–272. 1943.

MATERIALS AND METHODS

In the spring of 1951, 300 seed from apetalous flowers and 300 from petaliferous flowers were separated from each of 10 randomly chosen individual plants of commercial sericea. The separation was made on the basis of pod shape. Each type of seed from each plant was planted in 1-row plots in 3 randomized blocks. One hundred seed were planted per plot. A check plot of commercial sericea that included seed from apetalous and petaliferous flowers was planted, making a total of 21 entries. The test was conducted on a fertile river terrace soil. Excellent stands were obtained. Rows were 10 feet long and 20 inches apart. There was a distance of 1 foot between replications. Two hay cuttings were made in 1952 and in 1953, making a total of 4 cuttings. No hay cutting was made in 1954; instead, the plots were harvested for seed. Stand counts were made following seed harvest.

RESULTS AND DISCUSSION

Forage Yields

Forage yields were subjected to analysis of variance. The interaction, families × types of progeny, was not significant, indicating that the types of progeny reacted alike regarding forage yields in the 10 families. Yields of the chasmogamous progeny were significantly higher than yields of the cleistogamous progeny at the 1% level, and a highly significant difference was indicated among families. The yield of the commercial check was not significantly different from the average yield of the 20 lines.

For a 2-year period the chasmogamous progeny averaged producing 6,428 pounds of dry herbage per acre as compared to 5,134 pounds for the cleistogamous progeny, an increase of 1,294 pounds or 25% (table 1). The range of this increase between types of progeny varied from no increase to 41%, indicating considerable differences in the general combining ability and/or in the amount of cross-pollination of the petaliferous flowers among the 10 parent plants. The average forage yield of the 10 families (cleistogamous and chasmogamous progenies) for the 2-year period was 5,780 pounds, compared with 5,761 pounds for the commercial check from which the original 10 parent plants were selected.

Seed Yields

Analysis of variance of seed yields showed that the interaction, families × types of progeny, was not significant, indicating that the types of progeny yielded alike in the 10 families. Yields of the chasmogamous progeny were significantly higher than yields of the cleistogamous progeny at the 1% level, and a highly significant difference was indicated among the seed yields of the 10 families. The yield of the commercial check, from which the 10 selections were made, was not significantly different from the average yield of the 20 lines.

The chasmogamous progeny averaged producing 504 pounds of seed per acre as compared to 360 pounds for the cleistogamous progeny, an increase of 144 pounds or 40% (table 2). The range of this increase between types of progeny varied from no increase to 52%, again indicating considerable differences in the general combining

Table 1.—Average pounds of dry forage per acre per year produced by the cleistogamous and chasmogamous progeny of 10 sericea plants, 1952–53.

Family No.	Cleistogamous progeny	Chasmogamous progeny	Family means
1	4366	6092	5229
2	4566	4359	4462
3	5476	7173	6324
4	4579	5572	5076
5	4755	6710	5732
6	6046	7363	6704
7	5910	7346	6628
8	5316	7188	6251
9	5153	6553	5853
10	5171	5923	5546
Means	5134	6428	5780
Commercial mean	——	——	5761

Types of progeny 5% L.S.D. = 173.
Families 5% L.S.D. = 388.
Lines 5% L.S.D. = 548.

Table 2.—Pounds of unhulled seed per acre produced by the cleistogamous and chasmogamous progeny of 10 sericea plants. 1954.

Family No.	Cleistogamous progeny	Chasmogamous progeny	Family means
1	138	144	141
2	236	224	230
3	540	822	681
4	304	517	410
5	322	431	376
6	155	310	232
7	592	638	615
8	132	368	250
9	442	666	554
10	735	919	827
Means	360	504	432
Commercial mean	——	——	471

Types of progeny 5% L.S.D. = 62.
Families 5% L.S.D. = 138.
Lines 5% L.S.D. = 196.

ability and/or in the amount of cross-pollination of the petaliferous flowers among the 10 parent plants. The average seed yield of the 10 families was 432 pounds per acre, compared with 471 pounds for the commercial check.

In analysis of variance of stand counts the interaction, families × types of progeny, again was not significant, indicating that the types of progeny in the 10 families reacted alike in respect to stand. In this case there was no significant difference due to type of progeny. Also, there was no difference indicated in the stand of the commercial check and the other entries, although a difference was indicated among the 10 families at the 1% level.

A covariance analysis was made to determine whether yield differences were affected by stand, and, if so, whether adjustment for stand would change the conclusions concerning types of progeny differences. A highly significant relationship was found between stand and seed yields. The presence of an additional plant per plot increased seed yield by 12 pounds per acre. However, adjustment for stand differences did not materially change the yield relationship of the two types of progeny.

The average forage yield for the 2-year period of the 21 entries was compared with the seed yields of these entries and a non-significant correlation coefficient of $r = 0.39$ was obtained, indicating that there is not a close association between forage and seed yields in sericea.

These data indicate a significant degree of heterosis in sericea. Apparently, there is a marked difference in general combining ability and in persistence among individual plants as indicated by the performance of their progeny. A breeding method that utilizes hybrid vigor should produce varieties with increased forage and seed production.

It is recognized in the above discussion that the 10 parent plants may have differed considerably in degree of homozygosity. If a difference did exist, it undoubtedly influenced the magnitude of the differences in forage and seed yields between the two types of progeny of a given parent plant.

SUMMARY

A study was conducted to determine whether there are increases in forage and seed yields from hybrid seed of sericea and, if so, the magnitude of the increases. The results are summarized as follows: *(a)* Chasmogamous progeny of 10 randomly chosen individual plants yielded more forage and seed than cleistogamous progeny. The former produced 25% more dry herbage and 40% more seed than the latter. The range of this increase between types of progeny varied from no increase to 41% for forage and from no increase to 52% for seed. *(b)* Families varied considerably in forage and seed yields and in persistence. *(c)* No difference in the stand of the two types of progeny was indicated at the end of the fourth year in the field. *(d)* Forage and seed yields were not closely associated.

A Method for Studying Corn Root Distribution Using a Soil-Core Sampling Machine and Shaker-Type Washer[1]

J. B. Fehrenbacher and J. D. Alexander[2]

NUMEROUS methods have been employed to study the root systems of plants in soils. Pavlychenko (5) reviewed the methods used prior to 1937 and described the soil-block washing method. Weaver and Darland (8), studying soil-root relationships of native grasses in various soils, developed a method of sampling root systems of grasses by taking large soil monoliths of any desired depth and washing the roots contained therein free of soil. Fehrenbacher and Snider (1) used essentially the same method, as used by Weaver and Darland, to study corn root penetration and distribution in various soils.

In the present study of corn roots, samples around corn hills were obtained by use of the soil-core sampling machine of Kelley, Hardman, and Jennings (3). One of these machines belonging to the Agricultural Research Service of the U.S.D.A. at Urbana, Ill., was used. The objective in using it was the development of an easier and quicker method of sampling roots by soil horizons. Soil cores for sampling roots have been used previously by Laird (4) and Fitspatrick and Rose (2). They, however, used steel cylinders or steel pipes driven into the soil and had no convenient way of relating root development to soil profile characteristics.

In addition to sampling with a power-driven core sampler, a shaker-type washer was used for removing soil from the roots. Previous methods of washing roots have depended largely on a stream of water from special hose nozzles to dislodge soil. Upchurch (7) developed a soil-elution method of washing roots which avoided the loss of roots caused by directing a stream of water under pressure on a soil-root matrix resting on a screen. The shaker-type washing method described here depends on gentle shaking action of a soil-root-water mixture to put the soil into suspension before it passes through a 16-mesh screen. Water under pressure is not required.

MATERIALS AND METHODS

Each core taken by the Kelley soil-core sampler used in this study was 4 inches in diameter and 72 inches in depth. No special adaptation of the machine for root studies was needed, but some of the precautions necessary to insure undisturbed cores are noteworthy. Clean, well-oiled sleeves are essential to prevent compaction, and to facilitate removal of the sleeves after the core sample is taken. The sampler works best in moderately moist soil. If the soil is too dry, penetration is very slow and if the soil is wet, the cores are easily compacted. Maximum compaction of 6 inches occurred in the deepest horizon, D_1, of 2 of the 30 cores taken, but since there were very few roots in this horizon, the samples were not retaken.

While the core sampling machine worked well in the soil studied, which was derived from loess over loam till, it probably would not work in very gravelly, very sandy, or rocky soils. Loose soils would probably fall out of the tubes in the removal process, and rocky soils would be difficult or impossible to penetrate. About 1 hour was required for 2 men to take a soil core, cut it by horizons and bag it, and prepare the machine for another sample.

The shaker-type washer was constructed so that it could be easily disassembled for transportation. It consisted of a stand made of 2- by 6-inch fir on which a rack, containing 8 pans, was free to move back and forth on rollers made of 1-inch galvanized pipe (figure 1). The pans, 12 by 12 by 18 inches deep, were made of 1/16-inch sheet metal with the bottoms perforated by ½-inch holes centered 1 inch apart. The bottom of each pan was covered on the inside with 16-mesh copper screen; and the pans, when in place in the rack, extended down about 6 inches into a large, 32-inch wide, 66-inch long, 12-inch deep sheet metal pan filled with water. A 1/3-hp. electric motor, having a speed reducer unit coupled with a 2-inch and a 14-inch pulley and crankshaft assembly, gave a final speed of about twenty-two 4-inch strokes per minute to the rack containing the 8 pans.

In the operation of the washer, 1 horizon of 1 core was placed in each pan and allowed to shake for a period of ½ to 1 hour. Many factors such as texture, structure, organic-matter content, and moisture content, affect the time required to put soil in fine enough suspension to pass through a 16-mesh screen. The ½- to 1-hour period, however, was adequate for the soil studied, except for water-stable aggregates. These had to be crushed by hand after most of the roots had been skimmed off with small (6 by 6 inch) 16-mesh screens. The very small roots had to be separated from organic debris left from previous crops and picked off the screens with tweezers. The roots were kept in water in jars until they could be arranged in proper vertical position by horizons on black cloth-covered boards for photographing. Later they were oven dried and weighed.

One possible arrangement of the sampling location of the 4-inch diameter cores in duplicate in relation to a corn hill is shown in figure 2. It was not always possible to locate duplicate cores exactly opposite each other in the 4-inch wide ring they represented, but since it was assumed that the roots were symmetrically developed around the hill, the placement of the core at the proper distance from the center of the hill was the important consideration. Since the corn was checked in hills 40 by 40 inches, sampling in 5 concentric rings each 4 inches wide, as indicated in figure 2, gave measurements up to 20 inches from the corn hill or halfway to the adjacent hill. Each of the corn hills sampled had 3 ear-bearing stalks and was selected at random from 60-hill plot sections that were delineated on the basis of soil type.

With corn hills 40 by 40 inches apart and with 4-inch diameter cores taken in successive 4-inch wide rings away from the hill, it was very easy to expand the root weights of the core samples to a hill and to an acre basis. The calculated root weights are for a 3-stalk hill and 11,760 plants per acre. In this study no samples were taken in the area centered between 4 hills of corn and not covered by 40-inch diameter circles centered on each of the 4 hills. In future work this area should be sampled. It will add a small percentage to the total root weights per hill and per acre.

Samples were taken on an untreated or residue (R) plot and on a treated or residue-lime-rock phosphate (RLrP) plot on the

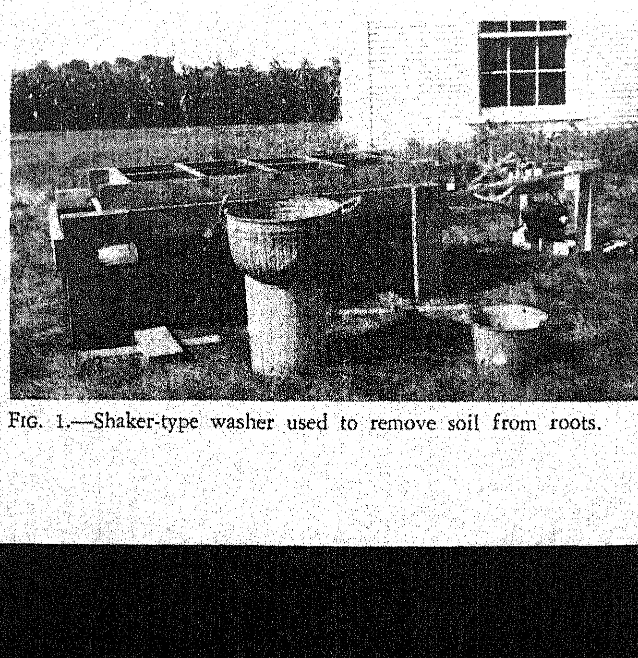

FIG. 1.—Shaker-type washer used to remove soil from roots.

[1] Contribution from the Dept. of Agronomy, Illinois Agr. Exp. Sta., Urbana, Ill. Published with the approval of the Director, Illinois Agr. Exp. Sta. Received May 6, 1955.

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N700 series on Flanagan silt loam on the Agronomy south farm at Urbana, Ill. The R plot had only crop residues returned to it, whereas the RLrP plot had limestone and rock phosphate applications in addition to crop residues, including legumes, turned under. On each plot, 1 hill was sampled in duplicate in a manner similar to that shown in figure 2, and 1 hill singly or with only 1 set of 5 cores. Both plots had a rotation of corn-corn-oats-red clover, and the sampling was done on the first-year corn, between Aug. 23 and Sept. 10, 1954, when the corn was dented and nearly mature. An adapted hybrid was grown. The grain and cob weights represent the entire 60-hill section of each plot and the stalk weights were derived from representative samples from each 60-hill plot section. The distance between the sampling sites on the 2 plots was about 40 feet.

The soil studied, Flanagan silt loam, is a dark-colored, permeable Brunizem developed from Peorian loess over loam till of Wisconsin age. Loess thickness on the 2 plots averaged about 55 inches. There were numerous krotovinas and worm holes in the profile above the D horizon. Some physical and chemical characteristics of the Flanagan profiles on the two plots are given in table 1. Horizon letter, texture, and structure designations given in table 1 are in accordance with U.S.D.A. Handbook 18 (6).

EXPERIMENTAL RESULTS

Root weights for both the untreated (R) and treated (RLrP) plots are given in table 2 by soil horizons for each 4-inch core sampled at various distances from the corn hill. In each case the two cores for hill A are duplicates. Hill B was not sampled in duplicate. For the R plot, the roots taken from the I_1, II_1, III_1, IV_1, and V_2 cores of hill A are shown in figure 3. The roots taken from the I_1 II_1 III_1, IV_2, and V_1 cores of hill A on the RLrP plot are shown in figure 4. Core V_1 of the R plot and core IV_1 of the RLrP plot were not used in the photographs because of slight compaction in the D_1 horizons.

The data presented in table 2 are not sufficient to study statistically root distribution with distance from the corn hill. Because of limited data, the weights of the three cores for each horizon at each distance from the hill were averaged (table 3) and used to calculate the root weights in grams per hill and pounds per acre of each plot. Calculated pounds of roots per acre-inch and percent of total roots

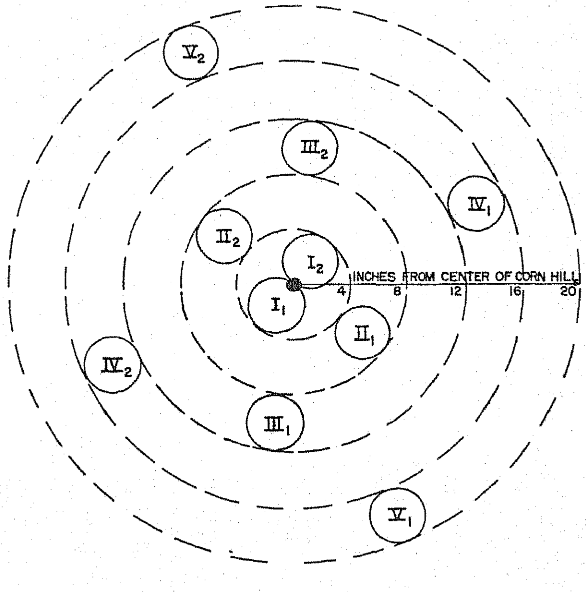

FIG. 2.—One possible sampling arrangement of the 4-inch cores in duplicate within concentric rings around a corn hill.

Table 1.—Physical and chemical characteristics of untreated (R) and treated (RLrP) Flanagan silt loam from Agronomy south farm, Urbana.

Soil horizon	Depth	Texture and structure	Moisture 1/3 atm.	Moisture 15 atm.	Available soil moisture capacity	pH	Constituents per 2 million lb. soil, Available P	Available K
	in.		%	%	acre-inches		lb.	lb.
			R plot					
Surface A_1	0–14	Silt loam; weak, fine crumb to moderate, medium granular	32.5	12.6	3.2	4.8	20	192
Subsurface A_3	14–18	Heavy silt loam; moderate, medium granular	32.0	14.8	0.8	5.6	12	192
Subsoil B_1	18–23	Light silty clay loam; moderate, medium granular to fine subangular blocky	31.6	17.2	0.9	6.1	12	216
B_2	23–39	Silty clay loam; moderately strong, medium subangular blocky	32.0	15.3	3.3	6.6	26	208
B_3	39–43	Light silty clay loam; weak, medium to coarse subangular blocky	31.6	13.9	0.9	7.2	136	172
Substrata C_1	43–54	Silt loam; nearly massive (loess)	32.0	10.2	3.2	7.5	200+	172
D_1	54–72	Loam; massive (weakly calc. till)	22.9	7.6	4.1	7.1	200+	172
			RLrP plot					
Surface A_1	0–16	Silt loam; weak, fine crumb to fine granular	32.4	14.0	3.4	5.0	184	172
Subsurface A_3	16–20	Silt loam; moderate, fine to medium granular	30.4	15.6	0.7	5.3	40	185
Subsoil B_1	20–24	Light silty clay loam; moderate, medium granular to fine subangular blocky	29.8	16.9	0.6	5.5	14	208
B_2	24–40	Silty clay loam; moderately strong fine to medium subangular blocky	30.4	15.0	3.0	6.2	30	185
B_3	40–46	Light silty clay loam; weak, medium to coarse subangular blocky to blocky	28.0	13.0	1.2	6.5	72	178
Substrata C_1	46–57	Silt loam, nearly massive (loess)	30.5	9.6	3.1	7.1	200+	178
D_1	57–72	Loam; massive (weakly calc. till)	26.0	8.4	4.0	7.2	192	148

Table 2.—Weight of corn roots per horizon per 4-inch diameter core at various distances from three-stalk hill on untreated (R) and treated (RLrP) Flanagan silt loam.

Soil horizon and depth	Dry matter weight														
	0–4 in. from hill			4–8 in. from hill			8–12 in. from hill			12–16 in. from hill			16–20 in. from hill		
	Hill A		Hill B	Hill A		Hill B	Hill A		Hill B	Hill A		Hill B	Hill A		Hill B
	I_1 core	I_2 core	I_3 core	II_1 core	II_2 core	II_3 core	III_1 core	III_2 core	III_3 core	IV_1 core	IV_2 core	IV_3 core	V_1 core	V_2 core	V_3 core
in.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
R plot															
A_1 0–14	2.86	3.77	3.42	0.43	0.71	0.70	0.54	0.48	0.48	0.44	0.32	0.40	0.25	0.30	0.27
A_3 14–18	0.40	0.33	0.36	0.17	0.12	0.22	0.21	0.15	0.17	0.20	0.20	0.17	0.10	0.16	0.10
B_1 18–23	0.43	0.22	0.27	0.16	0.17	0.24	0.24	0.20	0.17	0.21	0.30	0.16	0.18	0.17	0.13
B_2 23–39	1.32	0.99	0.80	0.93	0.54	0.67	0.57	0.45	0.55	0.66	0.59	0.50	0.33	0.47	0.34
B_3 39–43	0.26	0.18	0.29	0.15	0.10	0.15	0.09	0.06	0.10	0.14	0.15	0.12	0.05	0.05	0.05
C_1 43–54	0.20	0.24	0.18	0.27	0.12	0.15	0.15	0.13	0.16	0.06	0.08	0.10	0.02	0.02	0.03
D_1 54–72	0.02	0.03	0.02	0.01	0.02	0.02	0.06	0.02	0.05	0.04	0.02	0.01	0.01	0.01	0.04
Total	5.49	5.76	5.34	2.12	1.78	2.15	1.86	1.49	1.68	1.75	1.66	1.46	0.94	1.18	0.96
RLrP plot															
A_1 0–16	5.48	3.91	3.99	2.21	2.17	2.12	0.60	0.58	0.61	0.68	0.55	0.52	0.43	0.50	0.49
A_3 16–20	0.38	0.42	0.42	0.27	0.35	0.32	0.11	0.17	0.18	0.15	0.19	0.12	0.11	0.10	0.12
B_1 20–24	0.27	0.40	0.29	0.33	0.33	0.31	0.14	0.14	0.12	0.14	0.10	0.12	0.11	0.20	0.14
B_2 24–40	0.68	0.61	0.81	1.04	0.84	0.79	0.59	0.48	0.49	0.40	0.59	0.43	0.37	0.41	0.34
B_3 40–46	0.27	0.22	0.22	0.17	0.30	0.20	0.17	0.25	0.18	0.29	0.17	0.22	0.10	0.19	0.14
C_1 46–57	0.15	0.17	0.21	0.10	0.38	0.27	0.12	0.15	0.13	0.15	0.12	0.19	0.13	0.17	0.14
D_1 57–72	0.08	0.09	0.06	0.06	0.08	0.06	0.04	0.07	0.03	0.05	0.08	0.10	0.02	0.03	0.09
Total	7.31	5.82	6.00	4.18	4.45	4.07	1.77	1.84	1.74	1.86	1.80	1.70	1.27	1.60	1.46

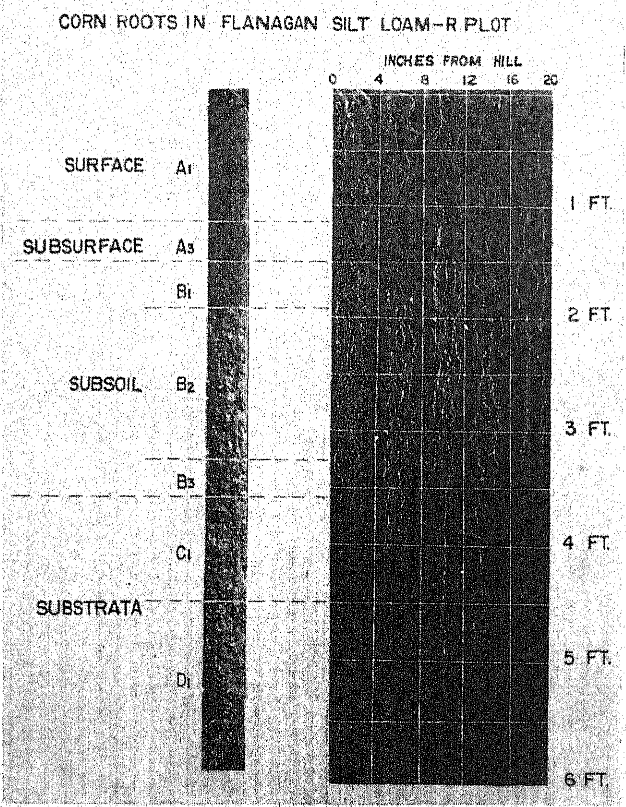

FIG. 3.—Corn roots from untreated (R plot) Flanagan silt loam with soil profile. Each of the five vertical panels of roots is from one 4-inch diameter core.

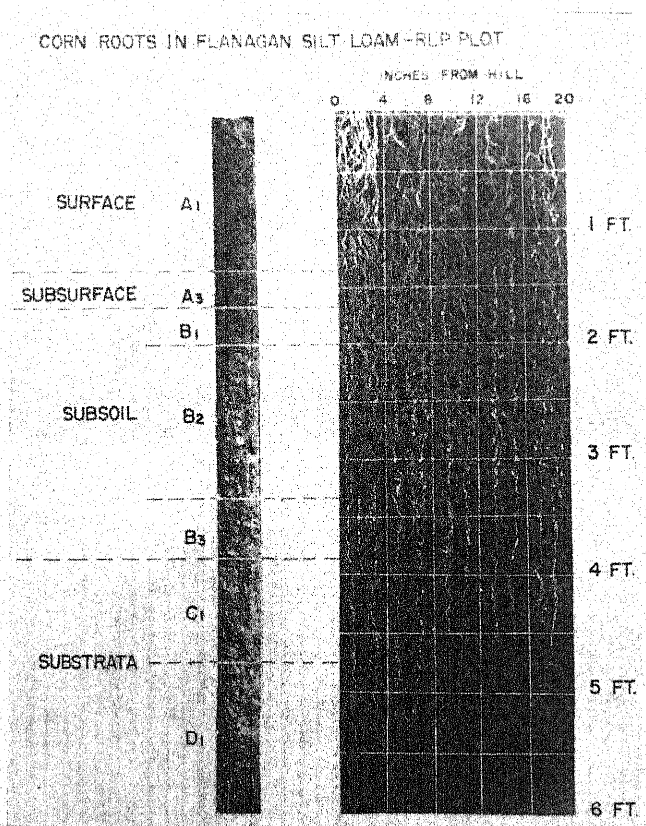

FIG. 4.—Corn roots from treated (RLrP plot) Flanagan silt loam with soil profile. Each of the five vertical panels of roots is from one 4-inch diameter core.

Table 3.—Calculated hill and acre weights of corn roots by horizons on untreated (R) and treated (RLrP) Flanagan silt loam.

Soil horizon	Depth	Dry matter weights: Ave. weights of hill A and B per 4-inch core: 0–4 in. from hill	4–8 in. from hill	8–12 in. from hill	12–16 in. from hill	16–20 in. from hill	Calculated per hill	Calculated per acre	Calculated per acre-inch	% of total
	in.	g.	g.	g.	g.	g.	g.	lb.	lb.	
				R plot						
A_1	0–14	3.35	0.61	0.50	0.39	0.27	51.36	444	32	31.8
A_3	14–18	0.36	0.17	0.18	0.19	0.12	16.72	145	36	10.4
B_1	18–23	0.31	0.19	0.20	0.22	0.16	19.44	168	34	12.0
B_2	23–39	1.04	0.71	0.52	0.58	0.38	53.00	458	29	32.7
B_3	39–43	0.24	0.13	0.08	0.14	0.05	9.84	85	21	6.1
C_1	43–54	0.21	0.18	0.15	0.08	0.02	8.96	77	7	5.5
D_1	54–72	0.02	0.02	0.04	0.02	0.02	2.40	21	1	1.5
Total		5.53	2.01	1.67	1.62	1.02	161.72	1398	—	100.0
				RLrP plot						
A_1	0–16	4.46	2.17	0.60	0.58	0.47	89.04	769	48	41.7
A_3	16–20	0.41	0.31	0.15	0.15	0.11	16.52	143	36	7.7
B_1	20–24	0.32	0.32	0.13	0.12	0.15	16.48	142	36	7.7
B_2	24.40	0.70	0.89	0.52	0.47	0.37	50.36	435	27	23.6
B_3	40–46	0.24	0.22	0.20	0.23	0.14	19.08	165	27	8.9
C_1	46–57	0.18	0.25	0.13	0.15	0.15	15.92	138	13	7.5
D_1	57–72	0.08	0.07	0.05	0.08	0.05	6.20	54	4	2.9
Total		6.39	4.23	1.78	1.78	1.44	213.60	1846	—	100.0

for each soil horizon are also given in table 3. Total calculated root weight on the untreated (R) plot was 1,398 pounds, whereas on the treated (RLrP) plot it was 1,846 pounds. Roots penetrated to about 48 inches on the R plot with a very few extending to about 60 inches, and to about 60 inches on the RLrP plot (figures 3 and 4).

Although the average weight of roots from 3 cores at each distance from the hill probably gave the most reliable estimate of total pounds of roots per acre, weights of roots per acre were also calculated using the 3 sets of cores on each plot separately. These calculated values for the separate sets of cores, as well as the averages, are presented in table 4. On both the R and RLrP plot there was less difference between calculated root weights per acre on the duplicate set of cores on hill A than between duplicate hills (hills A and B). Based on these limited data of 2 hills per plot, differences of 300 or more pounds of roots per acre between treatments as determined by this method would be statistically significant.

Yield of grain and dry matter in stalks, grain, and cobs, as well as root to top ratios, are also given in table 4.

Root weights per acre on both the R and RLrP plot, estimated by the method described here, appear to be in line with those reported for a different method used to study corn root penetration and distribution in Illinois soils (1). However, the percentage of roots in the A horizon was considerably less and the percentage of roots in the B horizon was considerably more in the Flanagan than in soils previously studied. Low rainfall during the 1954 growing season at Urbana may partially account for the

Table 4.—Summary of root weights, yield of corn (stalks, grain, and cobs), and root to top ratios on untreated (R) and treated (RLrP) Flanagan silt loam.

Hill	Core	Dry matter: Roots		Stalk	Grain	Cob	Total tops	Grain 15.5% moisture	Root to top ratio
		g./hill	lb./A.	lb./A.	lb./A.	lb./A.	lb./A.	bu./A.	
		R plot							
A	Subscript 1 cores	167.44	1447	—	—	—	—	—	1:4.1
	Subscript 2 cores	163.16	1410	—	—	—	—	—	1:4.2
	Ave. of subscript 1 and 2 cores	165.30	1428	—	—	—	—	—	1:4.2
B	Subscript 1 cores	156.20	1350	—	—	—	—	—	1:4.4
Ave.	of hill A and B, all cores	162.27	1402	2012	3123	859	5994	66	1:4.3
		RLrP plot							
A	Subscript 1 cores	212.60	1837	—	—	—	—	—	1:4.4
	Subscript 2 cores	221.48	1914	—	—	—	—	—	1:4.3
	Ave. of subscript 1 and 2 cores	217.04	1876	—	—	—	—	—	1:4.4
B	Subscript 1 cores	207.80	1796	—	—	—	—	—	1:4.5
Ave.	of hill A and B, all cores	213.96	1849	3463	3738	964	8165	79	1:4.4

greater percentage of roots in the B horizon. On the R plot, low available P in the A horizon (table 1) may have hindered root development to some extent. From a soil morphological standpoint, there appeared to be no serious restrictions to root development in the Flanagan soil profile. On the R plot, where the roots penetrated to about 48 inches, this soil had a storage capacity of about 10.5 acre-inches of available soil water. On the RLrP plots, roots penetrated to about 60 inches, and with the larger rooting volume, had a greater available soil moisture storage capacity (12.8 acre-inches) and a greater supply of nutrients to draw upon (table 1).

Root to top ratios of 1:4.3 on the R plot and 1:4.4 on the RLrP plot on Flanagan were similar to those on soils previously studied (1).

SUMMARY

A method of sampling roots in concentric rings around a corn hill with the Kelley soil-core sampling machine was devised. With this machine, satisfactory 4-inch diameter cores were taken to a depth of 6 feet in Flanagan silt loam.

A shaker-type washer was used to remove most of the soil from the roots. Final separation of the roots from the water-stable aggregates and from organic debris of previous crops was made with a small hand screen and tweezers.

Root weights per acre determined in this way appear to be in line with those obtained by the method of taking large soil-root monolith samples. The core sampling method eliminates the need for large pits and gives more complete sampling at various distances from the corn hill in less time.

A significant difference in amount of roots was found on a treated and an untreated plot on Flanagan silt loam. From the limited data, it was found that in uniform soil the roots were symmetrically developed around the corn hill and that there was less difference between duplicate sets of cores from one hill than between duplicate hills. Although the most efficient sampling pattern cannot be determined from these data, it appears that sampling more hills singly would give more reliable root weights per acre than sampling fewer hills in duplicate. Work to determine the most efficient sampling pattern on different soils is to be continued.

Roots penetrated to about 48 inches on the Flanagan silt loam R plot. To this depth, this soil is capable of storing about 10.5 acre-inches of available water. On the RLrP plot, roots penetrated to about 60 inches, and with the larger rooting volume, had a greater available soil moisture storage capacity (12.8 acre-inches) and greater supply of nutrients to draw upon.

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The Relationship of Seed Size to Seedling Vigor in Some Native Grass Species[1]

William R. Kneebone and Carlos L. Cremer[2,3]

SEEDLING vigor is particularly important in grasses seeded under the trying environments of the Southern Great Plains. Most of the native species recommended for the area are low in seedling vigor; all could probably be improved. This study was initiated to determine the importance of seed size and quality as related to seedling vigor improvement.

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REVIEW OF LITERATURE

Much of the literature on seed size effects in perennial grasses is European, principally British. In general, these studies have shown that within a lot, large seed gives the best seedlings, that between lots or strains the largest seeded ones have the best vigor and establishment, and that among species there is little relationship between seed size and seedling vigor. Nadvornik (5) found higher germination and vigor for large seed within a species and also showed (with ryegrass) that this difference was not due to more stored food alone since heavy seeds with part of the endosperm removed still grew better than lighter ones.

Davies (1) found that the overall correlation between seed

[3] The authors wish to express their appreciation for the careful and accurate work of H. W. Brown and C. R. Pearson, Scientific Aides, in screening, counting, weighing, and planting seed. Thanks are also due to Dr. F. Graybill of the Statistics Laboratory, Oklahoma A. & M. College, for suggestions and advice. Any errors of calculation and interpretation are the authors' own.

Table 1.—Weight 100 seeds, emergence, vigor score, and air-dry weight of seedlings from various sized buffalograss caryopses.*

Seed size	Weight 100 seeds in g.	Emergence %		Vigor score			Air-dry weight in g. Dec. 1952†
		13 days Feb. 1952	8 days Dec. 1952	Feb. 1952	Dec. 1952	Nov. 1954	
Screened							
1/16	0.236	50.7	64	1.4	1.0	2.0	0.40
1/18	.188	50.0	59	2.0	2.0	2.0	.32
1/20	.154	50.0	66	3.2	3.0	4.0	.21
1/22	.128	46.0	50	3.2	4.0	4.5	.17
Screened and aspirated							
1/16	0.238	53.3	70	1.8	1.0	2.0	0.31
1/18	.198	57.3	65	2.0	1.5	1.5	.33
1/20	.169	50.0	67	1.7	2.5	3.5	.23
1/22	.129	52.0	58	3.1	3.0	4.5	.20
L.S.D. 0.05		N.S.	N.S.	0.6	0.2	2.1	0.06

* Averaged from two replicates. Grown in sphagnum moss with nutrient solution of 5–7–5 fertilizer.
† For number seedlings given in column 4.

weight and percentage establishment in several tests for several species of grasses and clovers was 0.585. Species differences were independent of seed size. Comparing strains within species he found that the heaviest seeded strains gave best seedling establishment in perennial ryegrass, orchardgrass, and meadow foxtail. One exception was noted for timothy, other strains of timothy behaving as above. Milton (4) found that strains of perennial ryegrass and timothy with heavy seed gave better establishment than light seeded strains even though the same amount of seed was planted, giving more seeds per area for the latter. Hunt's (2) data on perennial ryegrass show a correlation of 0.798 between seed weight and number of established seedlings per 100 seeds planted.

In this country, Peace (6) obtained significant correlations, both phenotypic and genotypic, between seed weight and seedling vigor with 20 smooth bromegrass strains, indicating that selection for large seed could produce strains with increased seedling vigor. He emphasized, however, that when seed size was held constant in covariance analysis, the variance among strains was still significant, indicating that intensive selection for seedling vigor must be concerned with more than seed weight.

Rogler (7) studied emergence from various planting depths of seedlings from strains of crested wheatgrass producing seed of various sizes. He found high positive correlations between size of seed and emergence at 2 and 3-inch planting depths in both greenhouse and field with good correspondence of data between the 2 locations. Differences in emergence among size classes of seed were not significant at the ½, 1, and 1 to 12 inch depths, but seedlings from large seed were larger and grew more rapidly. He concluded that selection for large seed size was a direct method of increasing seedling vigor in crested wheatgrass.

Tossell[3] found differences among smooth bromegrass strains in rate of emergence, maximum stand, and vigor. Seed lots with high seed weights tended to be high for these factors. Seed weight classes within a seed lot showed distinct differences for the above characters, with large seeds superior. Height was associated with vigor and dry weight per seedling. Good agreement was found between greenhouse and field results. He suggested that greenhouse tests for seedling vigor be a regular part of a breeding program.

MATERIALS AND METHODS

Comparisons of size and weight classes of native grass caryopses were made over a 3-year period. The following data were used in comparisons: time of seedling emergence, number of plants emerged, seedling height at various intervals, green or dry weight per plot or per 100 seedlings, and seedling vigor scores. Vigor was scored 1–9 with 1 best. Seeds were planted in the greenhouse in the following media: ground sphagnum moss, sterilized, and unsterilized soil. In one case a germination test was made on moist paper toweling in petri dishes. One field trial was planted in sandy soil. Because of extreme drouth conditions this planting was sprinkler irrigated to foster establishment.

Hand screens were used to separate the caryopses into the various sizes planted. Each class of seed is indicated by the screen just small enough to hold it. Standard screen sizes are in fractions of an inch. Thus, a 1/20 screen has round holes 1/20 inch in diameter and a 6 by 20 screen has oblong holes 6/64 inch long and 1/20 inch wide. In the buffalograss test, each class of seed was separated into light and heavy fractions using an aspirator. Light seeds were discarded. Caryopses of the following were used in this study:

Buffalograss. *Buchloe dactyloides* (Nutt.) Engel. Bulk seed from a breeding nursery.
Indiangrass, *Sorghastrum nutans* (L.) Nash. Bulk seed from a breeding nursery.
Sand bluestem, *Andropogon hallii* Hack. Woodward strain and seed harvested near Cheyenne, Okla.
Sideoats grama, *Bouteloua curtipendula* (Michx.) Torr. Tucson, Logan, Hope, and Encinoso strains. Bulk seed from a breeding nursery.
Switchgrass. *Panicum virgatum* L. W2, Blackwell strains, and seed harvested near Woodward, Okla.

RESULTS

Results of buffalograss studies are given in table 1. The fraction of each seed class derived by aspiration was slightly heavier than its unaspirated counterpart and appeared to give a little more vigorous seedlings. Seed size had no apparent effect on germination in and emergence from sphagnum moss. Seedlings from large seeds were more vigorous than those from smaller ones.

In table 2 are data on sideoats grama and switchgrass. The sideoats grama gave results similar to the buffalograss, with no difference in emergence among size classes but distinct increases in seedling vigor with each increase in seed size. The switchgrass showed pronounced differences among size classes, in emergence as well as other vigor attributes. Seedlings from large seeds grew faster than those from small seeds.

Table 3 gives results from a test planted in 6 replicates, each replicate having 1 flat of methyl bromide sterilized soil and 1 flat of unsterilized soil. Considerable damping off occurred, most of it in the unsterilized soil, particularly in the sideoats grama. Because of many missing plots, little could be done in the way of statistical evaluation of the re-

[3] Tossell, W. E. The nature of variability of seed and seedling characters of smooth bromegrass, *Bromus inermis* Leyss. Unpublished Ph.D. thesis, University of Wisconsin Library, 1952.

Table 2.—Weight 100 seeds, emergence, height, and air-dry weight of seedlings grown from various sized sideoats grama and switchgrass caryopses.*

Seed source	Seed size	Weight 100 seeds in g.	Emergence %	Height in inches			Air-dry weight per 100 seedlings in g. 35 days
				14 days	34 days	Inc.	
Sideoats grama							
Tucson	6x34	0.070	68	2.3	6.8	4.5	0.97
	6x36	.057	72	2.2	6.4	4.2	.90
	6x38	.041	66	1.8	5.4	3.6	.62
Logan	6x34	.077	48	1.8	4.8	3.0	.59
	6x36	.061	53	1.7	4.2	2.5	.58
	6x38	.041	48	1.6	3.9	2.3	.37
Switchgrass							
Blackwell	1/20	0.174	82	1.3	5.9	4.6	1.17
	1/22	.134	64	1.1	5.0	3.9	.92
	1/24	.091	31	.8	4.6	3.8	.51
L.S.D. 0.05		—	5.7	0.5	0.7	—	0.45

* Averaged from four replicates. Grown in sphagnum moss with nutrient solution of 5–7–5 fertilizer.

Table 3.—Weight 100 seeds, germination, days to emergence, emergence, and total green forage produced per 100 seedlings from cuts at 4, 6, and 13 weeks following planting of some native grasses in sterilized and unsterilized soil.*

Seed source	Seed size	Weight 100 seeds in g.	Germination†	Days to emergence	Emergence	Total green weight per 100 seedlings in g.
			%		%	
Side-oats grama						
Hope	6x28	0.092	49.5	8.5	6.8	16.12
	6x38	.053	66.0	13.0	6.4	14.08
Encinoso	6x28	.099	63.0	9.0	9.7	31.03
	6x38	.052	71.5	9.4	12.5	19.95
Bulk	6x28	.097	88.0	12.9	18.0	17.23
	6x38	.054	74.5	13.6	15.3	14.90
Switchgrass						
W2	1/18	0.205	77.5	10.8	48.1	16.64
	1/24	.087	27.5	14.8	6.2	15.74
Blackwell	1/18	.202	46.0	10.7	25.1	19.72
	1/24	.100	25.5	13.9	11.4	15.33
Common	1/18	.200	53.5	13.8	18.9	22.02
	1/24	.095	18.5	14.9	8.0	18.08
Indian grass						
Bulk	1/18	0.297	87.5	11.1	21.1	13.15
	1/24	.158	75.5	12.4	21.4	9.83
Sand bluestem						
Woodward	6x18	0.393	95.5	11.1	26.9	9.54
	6x24	.187	90.0	12.2	29.1	7.54
Common	6x18	.385	23.5	14.2	4.5	12.74
	6x24	.184	21.0	14.6	3.3	10.27
L.S.D. 0.05		0.004	9.4	—	—	—

* Figures except germination averaged from 5–12 entries.
† Two replicates in petri dishes on moistened paper toweling.

sults. In most cases, however, differences were quite distinct between large and small seed classes. Of particular note was the earlier emergence from large seed. This was less apparent in earlier tests planted in moss.

Viability of switchgrass seed varied with size, small seeds germinating poorer than large ones. This difference was reflected in the emergence figures. The correlation between germination and emergence for the switchgrass data in table 3 was 0.933. Differences between seed size classes in green weight per 100 seedlings were apparently leveling out when the last cutting was made at 13 weeks from planting. The greater part of the yield was from that cutting.

Results of further greenhouse studies of switchgrass, indiangrass, and sand bluestem are given in tables 4 and 5. Seedlings from the smallest seed emerged more slowly than those from the larger classes. While differences in emergence were again pronounced only in the switchgrass, there were vigor differences in all species; the larger the seed the more vigorous were the seedlings. Height gave a good

estimate of yield, correlations being 0.758 and 0.873 for the data in tables 4 and 5 respectively. Height measurements made on the material in table 3 had a correlation of 0.542 with green weight at time of measurement.

Field results are given in table 6. In all cases but one, large seed gave earlier emerging seedlings than either bulk or small seed. Stands were thicker from bulk seed, in most cases, than from the large seed. Only in the switchgrass, however, were the stand differences of real significance. Small seeds gave much poorer emergence than either bulk or large seed. The field results in general agreed with those in the greenhouse. Although seeding rates were adjusted to give the same number of sound seeds per foot of row for each lot, there were probably more seeds of the bulk planted than either large or small seed, because of non-uniform seed weights and sizes.

Heights measured 33 days after planting showed that where significant differences occurred, they were generally in favor of large seed over small. Most differences, however, were not significant. The results for Blackwell switchgrass were not according to expectation and may be partly explained by the fact that two out of the three plots fell in slightly lower spots in the field and received more moisture.

Vigor ratings show that large seed was superior to small, while bulk seed tended toward intermediate values. Differences were again most marked in the switchgrass. Dry weights at the end of the first season did not, in most cases, differ significantly. The most striking difference (aside from the anomalous Blackwell switchgrass results) was in W_2 switchgrass. All plots with too poor a stand or growth too small and dried up to harvest were planted with small seed.

DISCUSSION

McAllister (3) found that seeds of several cool-season grasses harvested at pre-milk to milk stages were smaller than ripe seed and, although viable, gave fewer and weaker seedlings. Much of the range in seed size noted in this

Table 4.—Weight 100 seeds, days to emergence, emergence, height, and green weight 100 seedlings at 28 days for switchgrass planted in sterilized soil.*

Seed source	Seed size	Weight 100 seeds in g.	Days to emergence	Emergence %	Height in cm.	Green weight per 100 seedlings in g.
W2	1/18	0.205	10.0	68.0	11.0	1.69
	1/20	.170	10.0	77.0	11.3	1.21
	1/22	.123	10.7	52.0	8.0	.62
	1/24	.087	13.7	18.0	6.3	.35
Blackwell	1/18	0.202	10.0	27.3	9.6	2.02
	1/20	.162	10.3	16.0	12.3	1.68
	1/22	.135	10.3	16.0	9.6	1.25
	1/24	.100	13.3	6.3	7.6	.87
Common	1/18	0.200	11.3	35.3	10.6	1.25
	1/20	.175	11.7	33.3	9.3	.98
	1/22	.148	13.0	25.7	8.6	.82
	1/24	.095	13.7	10.0	9.0	.64
L.S.D. 0.05		——	0.69	8.4	N.S.	0.48

* Averaged from three replicates.

Table 5.—Weight 100 seeds, days to emergence, emergence, height, and green weight 100 seedlings at 28 days for Indiangrass and sand bluestem planted in sterilized soil.*

Seed source	Seed size	Weight 100 seeds in g.	Days to emergence	Emergence %	Height in cm.	Green weight per 100 seedlings in g.
Indian grass	1/18	0.297	7.0	61.3	14.0	2.10
	1/20	.253	7.0	49.3	13.6	1.87
	1/22	.207	7.0	55.0	12.0	1.36
	1/24	.158	8.0	45.7	10.6	1.21
Woodward sand bluestem	6x18	0.393	7.0	78.3	13.0	2.54
	6x20	.295	7.0	67.7	12.0	1.70
	6x22	.226	8.0	69.0	10.0	1.45
	6x24	.187	8.0	67.3	10.6	1.26
Common sand bluestem	6x18	0.385	11.0	17.3	13.3	2.53
	6x20	.280	12.3	17.0	10.0	1.20
	6x22	.220	12.7	12.0	9.0	1.12
	6x24	.184	14.0	10.3	7.0	.65
L.S.D. 0.05		——	——	9.6	1.7	N.S.

* Averaged from three replicates.

study, particularly in the apomictic sideoats grama strains Tucson, Hope, and Encinoso, could have been due to stage of maturity at harvest and other environmental effects. Some strains did have a higher average seed weight than others. Encinoso sideoats grama seed ranged primarily from 6x28 down to 6x34 while most of the Hope was from 6x32 down to 6x38. Since seed from these two strains was harvested at the same stage in adjacent fields during the same season, the seed size difference between them is probably of genotypic origin.

There was little difference in germination or emergence among size classes except in the switchgrass. Bilbro[4] compared seeds of different density separated from lots of sand bluestem and switchgrass by immersion in sucrose solutions of varying specific gravities. He got significantly higher germination from heavy seed in both species. This increase in germination, however, was not, he felt, worth the time and cost of density separation even for special studies.

The results obtained with native American grasses in this study agree substantially with published data for cool-season species native to Europe and Asia (1, 2, 4, 6, 7). Within each lot, large seeds gave the best seedlings. Differences in seedling vigor among species were not in accord with seed size. Within species there were strain differences in seedling vigor unassociated with seed size. Although no direct comparisons could be made on the basis of average seed sizes among strains, Encinoso sideoats grama, which has been generally superior in seedling vigor whenever planted, does have larger than average seed.

Some 12,000,000 acres in the Southern Great Plains area could be stabilized and made more productive if successfully reseeded with adapted warm-season native grasses. Other conditions being equal, it seems probable that large, plump, high quality seed will produce stands more surely and such stands will be grazable more quickly than those from small, shriveled poor quality seed. Selection of strains having large seed and good seedling vigor and their increase under optimum conditions for seed development should provide the type seed necessary for optimum results in reseeding.

[4] Bilbro, J. D. The relation of seed density to the germination of four grass species. Unpublished M.S. thesis, Oklahoma A. & M. College, Library, 1953.

SUMMARY

Buffalograss, indiangrass, sand bluestem, sideoats grama, and switchgrass caryopses were separated by hand screening into various classes.

Vigor of seedlings produced by the various seed sizes in various media in the greenhouse and in one field planting was evaluated in terms of vigor score, speed of emergence, stand, height, and forage production in early stages.

The larger the seed within a lot, the more vigorous were the seedlings from it. Seedlings from larger seeds emerged faster and grew at a faster rate.

Seed size had little effect on germination except in switchgrass. Small seeds of switchgrass germinated poorly in all tests.

Differences in average seedling vigor were noted both among species and among strains within species.

Table 6.—Days to 50% emergence, stand, vigor score, height at one month, and air-dry forage production from several native grass seed sources planted in rows in the field.*

Seed source	Seed size	Days to 50% emergence	Stand % 49 days	Height in cm. 33 days	Vigor 49 days	Air-dry forage end first season in g.
Side-oats grama						
Bulk	6x28	12.3	80.0	10.7	4.0	257
	Bulk	12.7	86.7	13.3	3.3	295
	6x38	13.7	71.7	11.3	4.3	177
Encinoso	6x28	13.0	53.3	15.7	3.0	176
	Bulk	13.3	70.0	16.3	3.7	200
	6x38	14.0	61.7	14.0	5.0	‡
Hope	6x30	12.3	75.0	14.0	3.7	244
	Bulk	13.3	53.0	13.3	4.3	150
	6x38	13.3	66.7	11.3	5.3	128
Switchgrass						
W2	1/18	15.7	71.7	16.0	2.7	404
	Bulk	14.3	88.3	11.3	4.0	295
	1/24	†	33.3	12.0	5.0	132
Blackwell	1/18	13.3	93.3	12.7	4.0	204
	Bulk	16.7	81.7	18.3	1.7	547
	1/24	†	10.0	8.3	7.3	‡
Indian grass						
Bulk	1/18	15.0	58.3	12.3	5.0	104
	Bulk	19.5	66.7	9.7	4.7	78
	1/24	20.0	63.3	9.0	5.0	82
Sand bluestem						
Woodward	1/18	13.5	70.0	13.0	4.0	203
	Bulk	14.0	73.3	11.7	5.0	163
	1/24	16.0	75.0	11.0	5.7	‡
L.S.D. 0.05		—	23.4	3.1	2.0	154

* Averaged from three replicates.
† Less than 50% stand.
‡ One or more plots missing, not included in analysis.

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Genotypic and Phenotypic Correlations in Soybeans and Their Implications in Selection[1]

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ESTIMATES of genotypic and phenotypic correlations among characters are useful in planning and evaluating breeding programs. A knowledge of the correlations that exist between important characters may facilitate the interpretation of results already obtained and provide the basis for planning more efficient programs for the future. Also, correlations between important and non-important characters may reveal that some of the latter are useful as indicators of one or more of the former.

The objectives of the present investigations were to estimate for two segregating populations of soybeans: *(1)* the genotypic and phenotypic correlations between all possible pairs of 24 characters, and *(2)* the degree to which certain characters or combinations of characters may be useful as indicators of high yield or oil.

Weiss (4) reviewed the literature prior to 1949 pertaining to correlations among various characters in soybeans and pointed out the inconsistency of the estimates obtained to that date. More recently Weiss *et al.* (5) reported significant positive correlations among the means of five varieties for the following characters: large seed and low iodine number of the oil; lateness of maturity and high oil content; lateness and low protein content; high oil content and low iodine number; and high protein content and low oil content. They also found that the correlations did not vary significantly among years, locations, or locations × years.

Weber and Moorthy (3) estimated genotypic and phenotypic correlations between all possible pairs of 7 characters measured in 3 F_2 populations of soybeans. They found that in general the genotypic correlations were higher than the phenotypic. They obtained positive genotypic correlations between flowering time and maturity date, yield and maturity date, yield and plant height, yield and seed weight, and negative genotypic correlations between flowering time and period from flowering to maturity, maturity date and oil percentage, and seed weight and oil percentage.

MATERIALS AND METHODS

Two populations of F_3 lines of soybeans were evaluated in the F_4 generation. Each line traced through bulked seed of F_3 parents to a single F_2 plant. Eighty-nine lines resulting from the cross Roanoke × Palmetto (population 1) and 64 lines from the cross N42-26 × Seminole (population 2) were evaluated. Lines of population 1 were grown at McCullers and Statesville, N. C., and Monetta, S. C., in 1950, and those of population 2 were grown at McCullers and Monetta only. The lines of a population were replicated twice in a randomized block design at each location. Eight viable seeds per foot of row were seeded in single rows 19 feet long and 3 feet apart.

A 16-foot section of each row was harvested for yield, and chemical data were obtained from a 60-g. sample of beans from each plot. Characters measured on a plot basis were as follows: *(1)* flowering time, recorded as the number of days from emergence to the date when half the plants in the plot were flowering; *(2)* fruiting period, recorded as the number of days from flowering to maturity; *(3)* maturity, recorded as the number of days from Sept. 1 to the date when all pods were ripe; *(4)* yield of seed in grams per plot; *(5)* seed weight, recorded as grams per 100 seeds (based on weight of 200 seeds per plot); *(6)* height at maturity in inches; *(7)* lodging, scored from 1 to 5, with 1 indicating almost all plants erect and 5 all plants lodged badly; *(8)* shattering (the plants remaining after the 16-foot section was harvested were scored from 0 to 5 approximately 2½ weeks after maturity, with 5 indicating over 50% shattering[3]); *(9)* protein percentage; *(10)* oil percentage; and *(11)* iodine number of the oil. Both oil and protein were computed on a dry weight basis.

Measurements were taken on 10 randomly-selected plants per plot at McCullers and Monetta and the 10-plant mean used as the plot values for the following: *(1)* number of branches; *(2)* number of nodes on main stem; *(3)* number of fruiting nodes on main stem; *(4)* average length of internodes of main stem; *(5)*

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[3] Since the scores for lodging and shattering are inverted with respect to the direction in which selection is practiced, the signs of the correlations between the 2 characters and the other 22 were reversed to facilitate the presentation of the data in terms of resistance to lodging and shattering.

Table 1.—Form of covariance analysis.

Source of variation	d.f.*	Composition of mean products
Locations	l−1	
Reps in locations	l(r−1)	
Lines	p−1	$cov_e + rcov_l + rlcov_p$
Lines × locations	(p−1)(l−1)	$cov_e + rcov_l$
Error	l(r−1)(p−1)	cov_e

* l, r, and p symbolize numbers of locations, replications per location, and lines, respectively.

number of pods per plant containing at least one fully developed seed; *(6)* percent of pods with one seed; *(7)* percent of pods with two seed; *(8)* percent of pods with three seed; *(9)* average number of seed per pod; *(10)* percentage of undeveloped ovules in pods containing one or more good seed; *(11)* number of seed per plant; *(12)* average number of seed per node; and *(13)* number of ovules per plant. Data on items 6, 7, 8, 9, and 10 were based on a sample of 20 pods selected at random from each of 10 plants per plot.

For each population all possible pairs of characters were analyzed by analysis of covariance and individual characters by analysis of variance methods. Results from the variance analyses of these data have already been reported (1). The form of the analysis is presented in table 1. From analysis estimates of cov_e, cov_l, and cov_p, the error, interaction, and progeny components of covariance, respectively were obtained. Since only 1 year was involved, cov_p contains the true line or genetic component, cov_s, and the component due to interaction of lines with years, cov_{sy}; and cov_l contains cov_{sly} and cov_{sl}, the components due to interaction of lines with locations and years, and lines with locations, respectively. The content of the components of variance for mean squares are analogous to those for covariance.

Table 2.—Genotypic and phenotypic correlations between all pairs of 24 characters measured at two or three locations—population 1 and 2 values are on right and left side of diagonal, respectively.

	Flowering time	Fruiting period	Maturity	Height	Yield	Seed weight	Res. to lodg.	Res. to shat.	Protein %	Oil %	Iodine No.
Flowering time*		−0.93 (−.90)†	0.34 (.29)	0.66 (.56)	−0.16 (−.09)	−0.16 (−.15)	−0.15 (−.13)	−0.02 (−.01)	0.14 (.10)	−0.27 (−.24)	0.24 (.20)
Fruiting period*	−0.94 (−.85)		.03 (.12)	−.57 (−.40)	.52 (.26)	.29 (.27)	.35 (.30)	.18 (.15)	−.23 (−.14)	.22 (.19)	−.18 (−.16)
Maturity	.41 (.28)	−.05 (.25)		.56 (.40)	.75 (.35)	.38 (.35)	.33 (.31)	.26 (.23)	−.02 (−.04)	−.22 (−.16)	.06 (.00)
Height	.38 (.31)	−.42 (−.30)	.14 (.11)		.22 (.31)	.11 (.14)	−.31 (−.21)	.24 (.20)	−.08 (−.06)	.00 (.05)	.19 (.07)
Yield	−.15 (−.09)	.27 (.14)	.40 (.36)	−.02 (.11)		.43 (.27)	.54 (.31)	.47 (.22)	−.64 (−.33)	.44 (.32)	−.08 (−.02)
Seed weight	.00 (−.01)	.12 (.13)	.36 (.32)	.06 (.06)	.66 (.45)		.27 (.22)	.16 (.15)	.09 (.11)	.12 (.12)	−.25 (−.23)
Res. to lodg.	−.21 (.18)	.06 (.09)	−.39 (−.34)	−.42 (−.39)	−.05 (−.13)	.03 (−.01)		.08 (.05)	−.07 (−.06)	.10 (.10)	.01 (.01)
Res. to shat.*	.18 (.09)	−.02 (.02)	.44 (.22)	.20 (.13)	.37 (.23)	.56 (.44)	−.20 (−.13)		−.63 (−.34)	.18 (.17)	−.02 (.01)
Protein %	.20 (.16)	−.25 (−.13)	−.05 (.03)	.00 (−.03)	−.12 (−.08)	−.13 (−.09)	.16 (.09)	−.39 (−.26)		−.48 (−.48)	.07 (.06)
Oil %	−.32 (−.31)	.30 (.23)	−.27 (−.28)	−.09 (−.07)	.02 (.00)	.18 (.15)	.11 (.11)	−.05 (−.04)	−.70 (−.69)		.03 (.03)
Iodine no.	−.02 (−.02)	−.04 (−.02)	−.23 (−.21)	−.19 (−.16)	.03 (.00)	−.50 (−.49)	−.01 (.03)	−.20 (−.16)	.09 (.08)	−.13 (−.12)	
No. branches*	.42 (.29)	−.47 (−.30)	.16 (.07)	.39 (.41)	.62 (.34)	.07 (.03)	−.51 (−.38)	.17 (.09)	.02 (−.05)	−.02 (.02)	.21 (.19)
No. nodes	.36 (.26)	−.31 (−.18)	.35 (.22)	.54 (.54)	−.14 (−.01)	.07 (.09)	−.03 (−.05)	−.11 (.01)	.32 (.25)	−.48 (−.39)	−.35 (−.27)
No. fruiting nodes	.06 (.02)	−.13 (.00)	.03 (−.02)	.31 (.32)	−.34 (−.02)	−.05 (.01)	.09 (.06)	−.34 (−.14)	.20 (.14)	−.37 (−.21)	−.49 (−.25)
Length of internodes	.18 (.16)	−.27 (−.22)	−.13 (−.06)	.72 (.70)	.06 (.15)	.02 (.01)	−.46 (−.41)	.27 (.14)	−.26 (−.24)	.29 (.24)	.04 (.03)
No. pods/plant	.20 (.08)	−.39 (−.12)	−.27 (−.21)	−.26 (−.03)	.28 (.15)	−.56 (−.33)	−.31 (−.29)	−.83 (−.18)	.00 (−.04)	.02 (.07)	.55 (.36)
1-seeded pods %	−.22 (−.13)	.47 (.25)	.05 (.08)	−.16 (−.14)	.41 (.12)	.26 (.15)	.29 (.29)	.27 (.06)	−.30 (−.15)	.35 (.18)	−.33 (−.22)
2-seeded pods %	.28 (.18)	−.43 (−.23)	.02 (−.02)	−.03 (.05)	−.17 (.01)	−.02 (.02)	.02 (−.08)	.04 (.06)	.23 (.12)	−.30 (−.17)	.36 (.25)
3-seeded pods %	−.09 (−.06)	−.02 (−.06)	−.08 (−.09)	.24 (.14)	−.30 (−.17)	−.29 (−.25)	−.39 (−.29)	−.40 (−.18)	.01 (.05)	−.06 (−.02)	−.04 (−.04)
Av. no. seed/pod	.06 (.04)	−.29 (−.19)	−.10 (−.11)	.22 (.16)	−.45 (−.17)	−.31 (−.22)	−.37 (−.31)	−.44 (−.13)	.22 (.11)	−.22 (−.11)	.20 (.14)
Undeveloped ovules %	−.06 (−.03)	.30 (.18)	.14 (.11)	−.09 (−.08)	.45 (.07)	.41 (.22)	.36 (.28)	.04 (−.01)	−.46 (−.22)	.57 (.28)	−.62 (−.38)
No seed/plant	.22 (.08)	−.53 (−.16)	−.31 (−.23)	−.18 (.06)	.11 (.10)	−.64 (−.36)	−.42 (−.25)	1.07 (−.20)	.08 (.00)	−.05 (.04)	.59 (.37)
No. seed/node	−.04 (−.02)	−.13 (−.08)	−.37 (−.28)	−.36 (−.17)	.12 (.10)	−.50 (−.37)	−.31 (−.23)	−.56 (−.19)	−.13 (−.13)	.20 (.21)	.58 (.44)
No. ovules/plant	.22 (.08)	−.44 (−.13)	−.28 (−.21)	−.21 (.04)	.21 (.12)	−.58 (−.34)	−.36 (−.21)	−1.12 (−.21)	−.02 (−.05)	.07 (.10)	.48 (.31)

Phenotypic correlations were estimated in the following manner:

$$r_{ph} = \frac{M_{12}}{\sqrt{(M_{11})\,(M_{22})}}$$

where M_{12} is the mean product for lines and M_{11} and M_{22} are the mean squares for lines for the characters (numbers 1 and 2) under consideration.

The genotypic correlations were estimated in a similar manner:

$$r_g = \frac{cov_{p12}}{\sqrt{\sigma^2_{p1}\,\sigma^2_{p2}}}$$

where cov_{p12}, σ^2_{p1}, and σ^2_{p2} are estimates of the progeny covariance component between a given pair of characters and the progeny variance components of the characters, respectively.

The expected change in one character as a result of selecting for another was estimated in the following manner:

$$\text{Expected change in unselected character} = \frac{k\,cov_{p12}}{\sqrt{\sigma^2_p + \dfrac{\sigma^2_i}{l} + \dfrac{\sigma^2_e}{rl}}}$$

where k is the expected mean phenotypic difference between the selected material and all material available for selection in units of standard deviations of the selected character, and the denominator of the fraction is the phenotypic standard deviation of the selected character, based on performance in r replications at each of l locations in one year.

Selection indices for yield and oil percentage and the genetic advance expected from selection based upon the indices were computed in the manner described by Robinson, Comstock, and Harvey (2).

Since cov_p includes both covariance in genotypic effects of lines (cov_g) and covariance in interaction effects between lines and

Table 2.—(continued). Genotypic and phenotypic correlations between all pairs of 24 characters measured at two or three locations—population 1 and 2 values are on right and left side of diagonal, respectively.

No. branches	No. nodes	No. fruiting nodes	Length of internodes	No. pods per plant	1-seeded pods %	2-seeded pods %	3-seeded pods %	Av. no. seed/pod	Undeveloped ovules %	No. seed per plant	No. seed/node	No. ovules/plant
0.53	0.63	0.40	0.20	−0.18	−0.24	0.26	−0.02	0.15	−0.27	−0.11	−0.53	−0.18
(.39)	(.53)	(.28)	(.16)	(−.13)	(−.22)	(.24)	(−.01)	(.14)	(−.24)	(−.09)	(−.40)	(−.14)
−.65	−.59	−.48	−.14	−.02	.22	−.20	−.05	−.17	.20	−.09	.34	−.02
(−.45)	(−.40)	(−.25)	(−.12)	(.00)	(.15)	(−.14)	(−.03)	(−.11)	(.13)	(−.04)	(.21)	(−.01)
−.08	.39	.06	.29	−.50	−.08	.26	−.25	−.06)	−.23)	−.49	−.67	−.54
(−.07)	(.30)	(.09)	(.16)	(−.30)	(−.09)	(.18)	(−.14)	(.00)	(−.19)	(−.28)	(−.45)	(−.32)
.45	.65	.34	.63	−.32	−.16	.13	.05	.11	−.22	−.25	−.64	−.30
(.40)	(.66)	(.37)	(.58)	(−.09)	(−.16)	(.15)	(.03)	(.11)	(−.19)	(−.05)	(−.43)	(−.08)
.09	.23	.29	.04	.14	−.25	.26	.00	.13	−.25	.18	.02	.10
(.14)	(.20)	(.22)	(.19)	(.21)	(−.18)	(.19)	(.01)	(.12)	(−.18)	(.23)	(.12)	(.20)
−.19	−.08	−.16	.25	−.55	.61	−.40	−.36	−.59	.46	−.72	−.56	−.59
(−.11)	(−.05)	(−.09)	(.23)	(−.33)	(.45)	(−.30)	(−.27)	(−.44)	(.33)	(−.42)	(−.39)	(−.37)
−.47	.02	.00	−.41	−.38	.18	−.22	.03	−.10	.02	−.41	−.27	−.38
(−.29)	(.08)	(.11)	(−.35)	(−.17)	(.06)	(−.11)	(.02)	(.01)	(−.03)	(−.16)	(−.17)	(−.17)
−.09	.16	.18	.15	−.02	.12	−.21	.10	−.01	.21	.01	−.15	.06
(−.07)	(.12)	(.12)	(.13)	(−.04)	(.02)	(−.08)	(.09)	(.04)	(.10)	(−.01)	(−.10)	(.00)
−.14	−.22	−.39	.09	−.61	.17	−.09	−.12	−.16	.10	−.64	−.36	−.58
(−.09)	(−.18)	(−.23)	(.05)	(−.34)	(.13)	(−.09)	(−.08)	(−.12)	(.07)	(−.35)	(−.23)	(−.34)
.03	.14	.39	−.11	.35	.22	−.13	−.14	−.23	.19	.24	.11	.29
(.07)	(.15)	(.28)	(−.06)	(.23)	(.10)	(−.04)	(−.09)	(−.12)	(.09)	(.18)	(.10)	(.21)
.22	.15	.19	.02	−.01	−.08	.20	−.16	−.04	.02	−.03	−.13	−.01
(.20)	(.03)	(.02)	(.02)	(.02)	(.01)	(.09)	(−.14)	(−.08)	(.06)	(.00)	(−.02)	(.01)
	.52	.48	.08	.15	−.13	.23	−.12	.01	−.07	.16	−.23	.13
	(.41)	(.38)	(.11)	(.33)	(−.09)	(.15)	(−.08)	(.02)	(−.03)	(.32)	(.07)	(.32)
.04		.87	−.18	.09	−.18	−.01	.27	.23	−.20	.16	−.51	.12
(.10)		(.81)	(−.17)	(.17)	(−.18)	(.04)	(.23)	(.23)	(−.19)	(.22)	(−.35)	(.19)
−.08	.80		−.43	.39	−.05	−.05	.15	.08	−.03	.39	−.22	.38
(.08)	(.75)		(−.34)	(.44)	(−.10)	(.00)	(.16)	(.15)	(−.08)	(.45)	(−.01)	(.45)
.45	−.20	−.34		−.51	−.02	.17	−.21	−.10	−.08	−.50	−.32	−.52
(.41)	(−.22)	(−.27)		(−.27)	(−.01)	(.14)	(−.20)	(−.10)	(−.03)	(−.27)	(−.19)	(−.29)
.46	−.40	−.28	−.01		−.03	−.04	.10	.01	.13	.93	.76	.96
(.52)	(−.01)	(.28)	(.04)		(−.08)	(.02)	(.09)	(.09)	(.04)	(.90)	(.80)	(.93)
−.16	.07	.33	−.24	.05		−.77	−.43	−.89	.88	−.35	−.16	−.11
(−.15)	(−.03)	(.00)	(−.16)	(−.14)		(−.80)	(−.42)	(−.90)	(.86)	(−.30)	(−.19)	(−.14)
.06	−.10	−.12	.04	−.08	−.67		−.25	.41	−.88	.11	.08	−.13
(.06)	(.00)	(.04)	(.07)	(.06)	(−.75)		(−.20)	(.48)	(−.83)	(.14)	(.11)	(−.02)
.12	.04	−.26	.24	.03	−.42	−.40		.77	−.10	.37	.14	.36
(.12)	(.05)	(−.05)	(.13)	(.10)	(−.38)	(−.31)		(.74)	(−.15)	(.28)	(.15)	(.27)
.17	−.06	−.41	.29	−.04	−.87	.22	.80		−.65	.36	.15	.20
(.15)	(.03)	(−.05)	(.16)	(.14)	(−.87)	(.37)	(.73)		(−.67)	(.33)	(.20)	(.22)
−.25	.07	.37	−.15	.00	.92	−.84	−.10	−.64		−.11	.04	.16
(−.19)	(−.03)	(−.01)	(−.09)	(−.16)	(.88)	(−.79)	(−.15)	(−.67)		(−.14)	(−.02)	(.06)
.48	−.40	−.39	.08	.94	−.24	.00	.31	.29	−.21		.76	.96
(.52)	(.00)	(.25)	(.08)	(.97)	(−.34)	(.15)	(.28)	(.37)	(−.31)		(.80)	(.92)
.35	−.75	−.68	.17	.86	−.23	.06	.21	.25	−.21	.90		.76
(.44)	(−.44)	(−.11)	(.18)	(.87)	(−.30)	(.14)	(.24)	(.33)	(−.29)	(.89)		(.81)
.44	−.40	−.36	.06	.96	−.03	−.20	.28	.14	.03	.97	.88	
(.50)	(.00)	(.26)	(.06)	(.98)	(−.18)	(.00)	(.26)	(.25)	(−.13)	(.98)	(.87)	

* Correlations involving shattering and the last 13 characters estimated from data from two locations only for population 1, and those involving shattering, flowering time, and fruiting period for one location only for population 2.

† Phenotypic correlations are in parenthesis.

years (cov_{sy}), estimates of cov_p are biased as estimates of cov_s if covariance in line-year interaction effects exist. Such bias may be either positive or negative depending on whether cov_{sy} is positive or negative. The situation is similar for the progeny variance (σ^2_p), except that this bias, if it exists, is positive since σ^2_{sy}, being a variance, cannot be negative. Thus the estimates of genotypic correlations were in reality of

$$\frac{cov_{s12} + cov_{sy12}}{\sqrt{(\sigma^2_{s1} + \sigma^2_{sy1})(\sigma^2_{s2} + \sigma^2_{sy2})}} \quad \text{rather than of} \quad \frac{cov_{s12}}{\sqrt{\sigma^2_{s1}\,\sigma^2_{s2}}}$$

and the biases referred to above could be a source of considerable bias in the estimates of genotypic correlations. However, examination of table 2 reveals a rather striking general agreement (in both sign and magnitude) between listed estimates of phenotypic and genotypic correlations. This suggests that for the most part the character correlations are similar for genotypic and non-genotypic effects and hence that the estimates of genotypic correlations as made were not seriously distorted by the fact that they reflect correlation in line-year interaction effects as well as in genotypic effects.

RESULTS

The correlations among characters measured on a plot basis were more consistent between the two populations than were those for characters measured on individual plants, and in general the genotypic correlations were slightly higher than the phenotypic (table 2). Long fruiting period, lateness, heavy seed, and resistance to shattering were appreciably correlated genetically with high yield in both populations, and genotypic correlations of yield with resistance to lodging, low protein, and high oil were near 0.5 in population 1 but negligible in population 2.

Oil and protein percentages were negatively correlated in both populations. High oil was genetically correlated to a limited extent with early flowering, long fruiting period, and earliness in both populations and with high yield in population 1, while high protein was negatively correlated genetically with resistance to shattering in both populations and with high yield in population 1.

The correlations presented in table 2 indicate that the 13 characters measured on individual plants have limited practical usefulness as indicators of high yield, oil, or protein, with the possible exception of number of branches as an indicator of yield in population 2. Number of branches was the easiest of the 13 characters to measure and in population 2 its heritability was almost twice that for yield (1).

The opposite direction and differences in magnitude of the correlations between various pairs of characters in the two populations demonstrate distinct differences in the relationships between characters in the populations. Thus there would be no reason to expect consistent associations between these characters in other segregating populations of soybeans.

Estimates of expected progress in improving yield by selecting for characters other than yield, expressed in percentage of the progress expected from selecting for yield itself, are presented in table 3. These estimates suggest that selecting for a long fruiting period, lateness, heavy seed, resistance to shattering, low protein, and high oil in both populations and resistance to lodging in population 1 should individually give improvement in yield, the amount varying with the different characters. The estimates in most cases are surprisingly high; however, the heritabilities of the characters considered are higher than for yield and one can select for them with a high degree of effectiveness. Therefore, since the characters are genetically correlated with yield, some, such as maturity in population 1 and seed weight in population 2, may actually be as good indicators of yield as yield itself.

In general, estimates of the progress expected in oil content from selecting for other characters (table 4) were substantially smaller than similar ones for yield. They were similar in magnitude in the two populations and indicate that selection for early flowering, long fruiting period, earliness, high yield, heavy seed, resistance to lodging, and low protein should be effective in increasing oil content.

Estimates of genetic progress in yield expected from the use of various selection indices, expressed in percentage of the progress expected from selection for yield, are presented in table 5. Selection based on a combination of fruiting period and seed weight appeared almost as effective as selecting for yield in population 1 and more effective in population 2. When lodging was considered in conjunction with the other two characters, expected progress was increased considerably for population 1 but scarcely changed for population 2. Addition of protein percentage

Table 3.—Progress expected in yield resulting from selection for other characters—expressed in percentage of the change expected when selection was for yield itself.

Character	Population 1	Population 2
Fruiting period	82.8	35.7
Maturity	110.0	57.4
Seed weight	68.2	105.4
Resistance to shattering*	65.6	52.6
Resistance to lodging	79.1	(—) 6.5
Protein %	(—)† 86.5	(—) 17.8
Oil %	67.3	3.7

* Data for two and one locations only for population 1 and 2, respectively.
† (—) indicates a negative association.

Table 4.—Progress expected in oil percentage resulting from selection for other characters—expressed in percentage of the change expected when selection was for oil percentage itself.

Character	Population 1	Population 2
Flowering time*	(—)† 29.2	(—) 32.6
Fruiting period*	22.6	26.9
Maturity	(—) 21.2	(—) 24.9
Yield	28.5	1.6
Seed weight	12.7	18.2
Resistance to lodging	9.5	9.7
Protein %	(—) 42.5	(—) 67.5

* Data for one location only for population 2.
† (—) indicates a negative association.

Table 5.—Progress expected in yield from selection based on a combination of characters—expressed in percentage of the change expected when selection was for yield itself.

Character	Population 1	Population 2
Fruiting period(1)	82.8	35.7
(1)+seed weight(2)	95.5	110.7
(1)+(2)+lodging(3)	107.8	111.1
(1)+(2)+(3)+protein %(4)	135.7	111.1
(1)+(2)+(3)+(4)+oil %(5)	136.0	115.0
(1)+(2)+(3)+(4)+(5)+yield	140.8	126.1

Table 6.—Progress expected in oil percentage from selection based on a combination of characters—expressed in percentage of the change expected when selection was for oil percentage itself.

Character	Population 1	Population 2
Flowering time(1)	29.2	32.6
(1)+fruiting period(2)	30.2	32.7
(1)+(2)+seed weight(3)	32.3	37.7
(1)+(2)+(3)+protein %(4)	54.6	72.3
(1)+(2)+(3)+(4)+Oil %	100.4	100.2

to the index had a similar effect to that obtained with the inclusion of lodging, while addition of oil percentage had little effect. The addition of yield to the index composed of the five characters mentioned above resulted in a small increase in the apparent efficiency of the index in both populations.

Expected progress from selection based on combinations of characters genetically correlated with oil was not appreciably greater than that from selection based on time of flowering alone, unless protein percentage was in the combination (table 6). Although improvement in oil content was indicated as a result of selection based on time of flowering or fruiting period (table 4), it appeared almost as profitable to use either character alone as to use the two in combination. This is because they are highly correlated with each other both genetically and phenotypically (table 2). Similarly, selection based on protein percentage alone appears almost as effective in improving oil content as selection based on protein percentage in combination with other characters, and the use of an index composed of oil percentage plus flowering time, fruiting period, seed weight, and protein percentage, all genetically correlated with oil percentage, appears no better than using oil alone.

DISCUSSION

Genotypic correlation coefficients provide a measure of the genotypic associations between characters and give an indication of the characters that may be useful as indicators of the more important ones under consideration. They also may help to identify characters that have little or no importance in the selection program. In any event, they provide basic information extremely useful to the breeder in understanding the species with which he works.

The practical utility of selecting for a given character as a means of improving another depends on the extent to which improvement in the major characters is facilitated by selection for the indicators. Such improvement depends not only on the genotypic correlations but also on the phenotypic correlations and the variances, both genotypic and phenotypic, of all characters included in the selection scheme or index. Characters which have no value in themselves and are not normally measured in the selection program are worthy of inclusion in the selection scheme only if their inclusion results in greater improvement of the important characters in terms of cost and/or time. In addition, correlations between indicator characters and those of major importance must be in the same direction in different populations if selection for the indicator characters is to be of general utility.

Genotypic correlations among characters for which selection is practiced may have important implications in breeding procedures. Johnson, Robinson, and Comstock (1) pointed out that effective selection for yield in soybeans is more difficult and requires more replications over years, locations, and in individual tests than selection for other important characters. They also reported data indicating that effective selection for such characters as length of fruiting period, maturity, height, seed weight, resistance to lodging and shattering, and oil and protein percentages could be practiced at one well-chosen location in one year. They suggested a breeding procedure in which selection for important characters other than yield is practiced in early generations, while seed supplies are built up for more extensive testing for yield. If the effectiveness of some of the individual characters or combinations of characters as indicators of yield reported in this paper were of general occurrence in segregating populations of soybeans, breeders could easily and efficiently improve yield by selecting for other characters in early generations. The magnitude of genotypic correlations and the weights assigned to various characters used in selection indices will vary from one population to another, but this variability is of secondary importance as long as a positive effect relative to yield is associated with selection for other characters in the direction that is natural for the characters in question.

Negative genotypic correlations between characters selected for in a breeding program may result in a reduction in the rate of improvement for some of the characters in comparison to the improvement that could be attained if the correlation were positive or non-existent. For example, assuming that the negative correlation between resistance to shattering and protein percentage (table 2) is representative of segregating soybean populations, selection for resistance to shattering has reduced the probabilities of finding high-protein genotypes. Selection for resistance to shattering is done quite effectively in the F_2 and F_3 generations of a cross, and selection for protein percentage is not normally practiced prior to the F_4 generation. Thus, early selection for shatter-resistant genotypes, which also tend to be low-protein types, would result in the discarding of some of the high-protein genotypes before they were even evaluated for protein.

The correlations between characters normally considered in soybean breeding programs (table 2) indicate that character associations are in general favorable to the breeder as long as the relative emphasis in breeding for oil and protein continues in favor of oil. However, should economic conditions necessitate a reversal in this relative emphasis, the negative correlations between yield and protein percentage and between resistance to shattering and protein percentage, if they are general in occurrence, may prove to be serious limitations in breeding for high protein.

It should be pointed out that the correlations between resistance to shattering and yield or between susceptibility to shattering and protein content were not caused by loss of beans due to shattering. The shattering notes were taken approximately 2 weeks after harvest and little or no shattering had occurred at the time of harvest.

A probable explanation of a part of the difference between the correlations of resistance to lodging and yield in the two populations (table 2) also should be pointed out. Lodging of both parents and the lines in population 1 frequently resulted in the loss of dominance in the terminal bud and the decay of a high percentage of the leaves and flowers that were shaded. In contrast, lodging of the Seminole parent and many of the lines in population 2

Table 7.—Plot means for characters measured on parental varieties and lines.*

Character	Population 1, 3 Locations			Population 2, 2 Locations		
	Roanoke	Palmetto	Lines	N42-26	Seminole	Lines
Flowering time†	64.0	79.7	70.9	64.0	76.0	69.6
Fruiting period†	94.2	75.6	87.2	89.5	83.8	86.9
Maturity	61.9	59.0	61.9	62.8	68.5	66.3
Height (in.)	39.7	50.0	45.8	41.8	44.4	42.1
Yield (Bu./a)	35.8	25.8	31.8	34.1	31.4	32.2
Seed weight (G./100)	17.1	12.2	14.6	15.3	29.7	21.4
Lodging	2.8	3.9	3.4	2.6	3.8	3.1
Shattering‡	.7	3.5	2.4	1.3	1.2	1.7
Protein %	40.1	43.7	41.8	42.8	44.0	43.5
Oil %	21.4	17.8	19.4	19.4	17.5	18.6
Iodine number	134.4	136.8	134.2	135.7	135.3	136.8
No. branches§	2.0	3.5	2.8	2.7	1.9	2.2
No. nodes	15.1	19.5	17.5	17.4	19.3	18.1
No. fruiting nodes	10.9	13.2	12.2	12.1	11.6	12.0
Length of internodes (in.)	2.4	2.6	2.5	2.4	2.3	2.3
No. pods/plant	41.6	52.4	47.6	44.2	27.8	38.5
1-seeded pods %	27.2	22.6	24.2	29.6	20.2	26.2
2-seeded pods %	65.3	71.6	68.6	63.7	65.8	66.4
3-seeded pods %	7.5	5.8	7.2	6.7	14.0	7.4
Av. no. seed/pod	1.8	1.8	1.8	1.8	1.9	1.8
Undeveloped ovules %	11.9	8.9	11.0	14.6	9.2	12.5
No. seed/plant	75.1	95.9	87.3	78.7	54.0	70.0
No. seed/node	5.0	4.9	5.0	4.5	2.8	3.9
No. ovules/plant	85.3	105.0	98.0	92.1	59.3	79.9

* Means of five entries of each parental variety per replication in population 1 and three entries per replication in population 2; line means are means of all lines in the sample.
† For one location only for population 2.
‡ For two and one locations only for population 1 and 2, respectively.
§ Means for last 13 characters from data at two locations only for population 1.

did not break the dominance of the terminal bud or result in excessive loss of leaves or flowers from shading.

It is recognized that linkage complexes could be a source of differences in the correlations among characters in segregating populations of soybeans. However, means of the various characters in the parental varieties (table 7) and the correlation coefficients in table 2 provide no consistent evidence on the effects of linkage in this study. In some cases, such as heavy seed and high yield, the character associations in the parents and lines were in the same direction in one population and reversed in the other. Since soybeans have 20 pairs of chromosomes, it would seem logical to expect recombinations of genes conditioning quantitative characters to approach random assortment. Nevertheless, the number of correlations indicating that character associations in the lines were in the same direction as those in the parents appears to be in excess of that expected on the basis of chance alone. Linkage cannot be eliminated as a source of some of the correlations, but it is apparently not the source of some of the larger and more consistent ones, which must have arisen from the fact that the characters are affected by some of the same underlying processes in the plant.

SUMMARY

Twenty-four characters were studied in the two populations of F_3 lines of soybeans in the F_4 generation. The lines of 1 population were evaluated at 2 locations, and those of the other at 3 locations in 1950.

Genotypic and phenotypic correlations between 13 characters measured on an individual plant basis and yield, oil percentage, and protein percentage were generally low and inconsistent between the two populations. The characters were considered to have little value as indicators of yield, protein percentage, or oil percentage. Correlations between characters measured on a plot basis were more consistent and in general the genotypic correlations were slightly higher than the phenotypic. The following genotypic correlations were appreciable in magnitude in one or both populations and may be of practical value in selection: high yield with long fruiting period, lateness, heavy seed, resistance to shattering and lodging; and low protein with high oil and resistance to shattering. Oil percentage was more strongly correlated with early flowering, long fruiting period, and early maturity than with other characters; however, correlations involving oil percentage generally were low in magnitude.

Estimates of the progress expected in yield from selecting for other characters genetically correlated with yield varied considerably between the two populations. They indicated that selecting for a long fruiting period, lateness, heavy seed, resistance to shattering, low protein, and high oil in both populations and resistance to lodging in population 1, in varying degrees should be effective in increasing yield. Similar estimates for oil percentage were smaller in magnitude but more consistent in the two populations. They indicated that selection for early flowering, long fruiting period, earliness, high yield, heavy seed, resistance to lodging, and low protein should be effective in increasing oil percentage.

Estimates of genetic progress in yield expected from the use of various selection indices indicated that selection based on the combination of fruiting period and seed weight would be essentially as effective as selection for yield itself in both populations. Addition of resistance to

lodging, oil percentage, and protein percentage to the index resulted in a moderate increase in its efficiency. Indices for oil content were considerably less effective than selections based on oil percentage itself, and even when oil percentage was included in the index the indicated progress did not exceed that expected from selection for oil alone.

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Development of Pods and Seeds of Birdsfoot Trefoil, *Lotus corniculatus* L., as Related to Maturity and to Seed Yields[1]

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EXPERIMENTAL trials and farmers' experiences have shown that the primary factors limiting the value of birdsfoot trefoil, *Lotus corniculatus* L., as a forage legume are low seed yields and lack of seedling vigor. Birdsfoot trefoil is known to have a high potential seed yield but seed pods dehisce freely upon ripening. In addition, indefinite flowering habit makes it difficult to judge the proper time for seed harvest. Flower formation, immature and ripening pods, and dehiscing of pods have been observed (1, 5, 6, 7) on an individual plant.

There is a lack of agreement (1, 4, 8) on the proper stage of maturity to harvest for seed. Recommendations were for the most part, vague in regard to what specifically determined a ripe pod. MacDonald (6) found that further development of seed viability, size, and weight was not appreciable after pods were greenish white, or sprinkled with brown. At this time the seeds were in the late dough stage. Hickel (3), Schribaux (9), and Bussard (2) indicate that normally dehisced seeds of birdsfoot trefoil have a high percentage of hard seeds, but that threshed seeds were lower in hard seed content due to scarification by the thresher. MacDonald (6) recognized hard seed as a problem of major consequence. Hughes *et al.* (5) found that maximum germination could be attained by scarifying the seed once and that additional scarification injured seed.

Difficulties in seed production have resulted in very high seed costs of domestic seed and have been a primary obstacle to more rapid use of this forage legume. The purpose of this investigation was to study basic factors in seed and pod development as related to the proper stage of maturity to harvest birdsfoot trefoil for maximum seed yields.

MATERIALS AND METHODS

All investigations reported in this study were made using the domestic type (Empire strain) of broadleaf birdsfoot trefoil with plantings made in the spring of 1951 on the Agronomy Farm at Ames, Iowa. A nursery of clonally propagated single plants was used for critical measurements of pod and seed development. A pure stand was established in an adjacent area for additional experiments.

The harvested plots requiring threshing were mowed with a small plot mower with a 36-inch cutter bar. Herbage was cured on individual strips of sisalcraft paper to prevent loss of dehisced seed and stored in heavy burlap bags for 3 to 4 months until threshed with a small grain plot thresher. Seeds were thoroughly cleaned, weighed, and calculated seed yields reported in pounds per acre on an air-dry basis.

Germination tests were made on blotter paper in petri dishes and allowed to germinate at 75° F. for 8 days. Some of the seed lots were scarified to compare the results with unscarified lots of the same seed.

All replicated experiments in this study were randomized complete block designs. At least 4, and in some cases, 5 and 6 replications were used, depending on available land area.[3] Four experiments were conducted in 1952 and 1953 to measure the relationships between stage of maturity and seed yields and quality.

A study was made in 1953 to determine the number of days required to produce morphologically mature seed, using a clonally propagated single-plant selection typical of the Empire strain. Budding umbels were tagged at two dates, June 13 and 17. On June 14 and 18, the umbels were in full bloom, which was considered as the date of pollination. Thirty umbels were harvested on successive 3-day intervals after full bloom and the length of initial pod from each umbel was measured and recorded. On the ninth day, in each group, seed was recovered after drying the pods. Two hundred seeds from each harvest were initially dried at 100° F. and later dried to a constant weight to determine moisture percentages.

Studies were conducted in 1952 and 1953 to determine the quantity and quality of seed produced in umbels as they approached maturity. In 1952, pods were harvested at four stages of development. Samples of immature pods, ranging from purple to light green in color, were harvested 18 days after full bloom. Six days later light brown pods were harvested. Samples of dark brown and black colored pods were harvested each on successive 4-day intervals following the light brown stage. One hundred represen-

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[3] The procedures outlined by Tukey (10) were followed to measure differences in treatment means.

tative umbels were collected from each plot in each of 5 replications and held in dry storage for further study of seed yields and germination.

A more precise test on pod maturity was made in 1953. About 125 umbels in bud stage were tagged on June 19 in each of 5 plots replicated 5 times. Flowers were fully open on June 20. Pods were harvested on July 8, July 12, July 16, July 20, and July 24. Pods were given the following color classification in order to harvest date: dark green, light green, light brown, dark brown, and black, respectively. The pods were dried for further study of seed yield, germination, and weight per 1,000 seeds.

In the third experiment, conducted in 1952 and 1953, plots were harvested at successive dates starting at rather immature through mature pod stage. Samples, 20 by 3 feet in area, were harvested at each date from 6 replications in 1952. The procedure in 1953 was similar, but due to shortage of area for conducting the experiment, only four replications were used. Data on seed yield, seed size, pod maturity, and germinations were tabulated. Representative samples of 100 light brown umbels were taken from the borders of plots at each date in the above experiments to determine the number of pods per umbel and number of seeds per pod at each date. This was the fourth experiment of this study.

EXPERIMENTAL RESULTS

Development of the Seed and Pod

An attempt in this investigation was made to determine the number of days after bloom required to produce "morphologically mature" seed. Morphological maturity is used here to indicate the stage of seed development where no further increase in dry weight was attained.

Pod length increased rapidly following pollination (figuse 1) and reached about three-fourths their final length within 6 days and maximum length by the 21st day. Noticeable diametrical development of the pods began about the 15th day, due to rapid seed development at this stage.

It was observed that pods progressed through rather definite color changes in their development. Pods were first a waxy, deep green color when very young, changed to a deep purple color approximately 1 week following full bloom and again to a dark green color soon after the 15th day. Pods remained dark green for about 1 week, and at this time they increased greatly in diameter. During the period from 21 to 24 days after full bloom, there was a noticeable change to a light green watery color and within 3 or 4 additional days the pods changed to an oily, light brown color. The color changes were rather rapid at this point, changing to dark brown in 3 or 4 more days. At about 32 to 34 days after full bloom, the pods were black. These color changes were consistent and are important in estimating the proper stage of maturity to harvest the seed crop.

Seeds were too small to separate from pod fragments until the ninth day after full bloom. Even the 9-day old seeds were extremely small and immature. Rapid seed development began (figure 2) at about the 15th day following full bloom and progressed until the 24th day when further development was small. It was possible that morphological maturity of seed was reached between 24 and 27 days, at which time the pods changed from watery, light green to an oily, light brown color. As nearly as calculations from both experiments permit, morphological maturity of seeds was attained 27 days following full bloom (figure 2).

An estimate of moisture content of the seeds at morphological maturity indicated that seeds contained approximately 35 to 40% moisture.

Pod Color in Relation to Stage of Maturity to Harvest

In 1952, samples of 100 umbels per plot were harvested 18 days after full bloom when the pods were dark green in color. Samples were taken later at light brown, dark brown and black color stages as they appeared. Highly significant differences were found in seed yield and probable live seeds in this experiment, with the difference clearly defined as a result of the inferior seed produced by the green pods.

In 1953, samples of 100 dark green pods were harvested 19 days following full bloom, followed by harvests of light green, light brown, dark brown and black pods, each at subsequent 4-day intervals. Seeds produced from immature dark green pods were inferior in all respects, yet immature light green pods produced seed of high quality equal to seed from light brown to black pods (table 1).

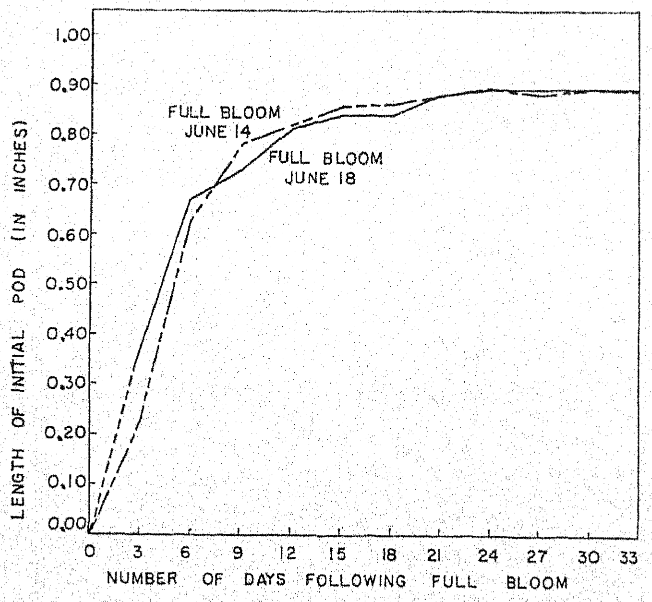

FIG. 1.—Development of the initial pod in birdsfoot trefoil at successive stages of growth following full bloom.

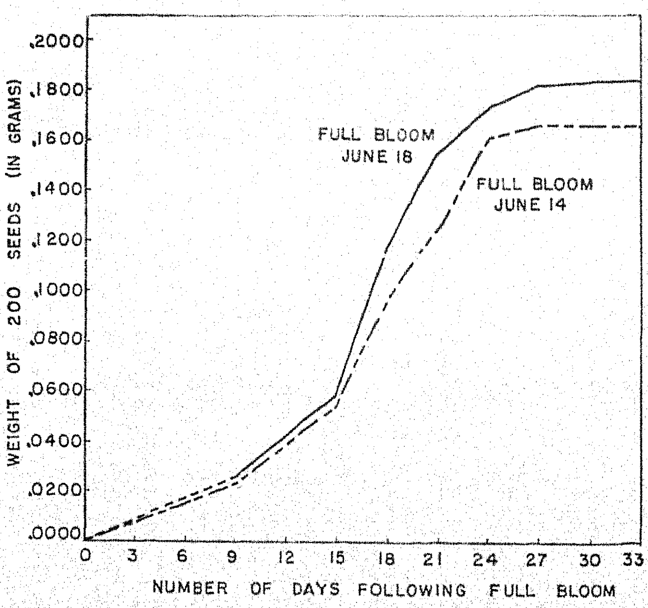

FIG. 2.—Development of the seed of birdsfoot trefoil at successive stages of growth following full bloom.

Table 1.—Seed weight, seed yield and germination of birdsfoot trefoil in 1953 at successive stages of maturity, as indicated by pod color.

Stage of maturity based on pod color	Weight per 1000 seeds	Seed yield per 100 umbels	Germination					
			Unscarified			Scarified		
			Germ.	HS	PLS†	Germ.	HS	PLS
	(grams)	(grams)	%	%	%	%	%	%
Dark green	0.66	2.51	11	27	38	43	2	45
Light green	1.01	5.29	14	76	90	86	1	87
Light brown	1.02	5.10	11	79	90	85	1	86
Dark brown	1.02	5.75	12	77	89	88	2	90
Black	1.01	5.26	13	73	86	85	1	86
Allowance*	.08	.71	—	—	11	—	—	8

* Allowance—Tukey's (16) allowance used to measure individual differences.
† Probable live seed.

Table 2.—Pod development, seed yields, seed weight and germination of birdsfoot trefoil harvested at successive dates in 1952.

Date harvested	Estimated percentages of pod development							Seed yield (Lb./A)	Weight per 1000 seeds (grams)	Percentages of		
	Bloom	Im-mature	Green	Light brown	Dark brown	Black	De-hisced			Germi-nation	Hard seeds	Probable live seeds
July 13	5	26	31	28	10	0	Tr.	135.2	0.930	54	14	68
July 15	2	14	21	33	25	5	Tr.	131.0	0.935	59	17	76
July 17	Tr.	9	12	35	36	8	Tr.	131.0	0.961	60	14	74
July 19	0	6	10	19	39	25	1	140.9	0.951	64	16	80
July 21	0	3	4	12	30	49	2	157.2	0.971	65	18	85
Allowance	—	—	—	—	—	—	—	47.9	.089	—	—	7

Normally dehisced seeds contained a large percentage of hard seeds in both years. Since actual value of hard seeds may be misinterpreted, representative samples of seed from each stage were scarified before germination to compare with unscarified lots. In both scarified and unscarified lots, the differences in germination based on probable live seeds, were highly significant, as were differences in weight per 1,000 seed yields.

Germination tests were conducted from lots of normally dehisced seed, seed threshed by a combine, and seed threshed with a small grain plot thresher. The combined seed contained approximately 50% hard seed, normally dehisced mature seed 70 to 75% and seed from the small grain plot thresher only 20 to 25% hard seeds.

Seed Yields and Viability As Affected by Dates of Harvest

Plots harvested in 1952 on successive 2-day intervals (table 2) revealed no differences in seed yield or weight per 1,000 seeds from relatively immature to mature stages of development. The majority of the pods were dark green to light brown when the initial harvest was made on July 13. Subsequent harvests followed until pods were mostly mature (pods dark brown to black) on July 21. Because the herbage was placed in bags to dry immediately after harvest, seed losses from shattering were limited to that which occurred prior to harvest.

The germination of seed on successive dates of harvest increased from 68 to 85% as pods advanced in maturity. Differences in germination exceeded the 1% level of significance.

In 1953, the results were different from those obtained in 1952 in regard to seed yield and seed size (table 3). Seed yields were greatly reduced in the latter dates of harvest. It is postulated that the differential response to harvest dates was due to lower relative humidity in 1953 than in 1952. Pod dehiscence was higher in 1953. It was evident that when the relative humidity decreased to approximately 40% and less, ripe pods dehisced freely. For example in the 1952 experiment, in no case did the relative humidity drop below 50% and the maximum dehisced pods was 2% even though 93% (table 2) of the pods were light brown to black. The data collected on July 8, 1953 harvest showed no dehisced pods (table 3). Five percent of the pods were dehisced on July 11 following low relative humidities of 40, 31, and 44% on July 9, 10, and 11, respectively. Only mature pods had dehisced according to data collected each year. Immature light green pods, containing high quality seed did not dehisce even under conditions of low relative humidity. Very little pod dehiscence occurred from July 11 to 14, and it was noted that the relative humidity ranged from 60 to 65% on July 12, 13, and 14. Very low relative humidities occurred on July 19 and 22 (38 and 32%, respectively) resulting in large losses of seed from the last two dates of harvest (table 3).

The temperatures during this period also could have contributed to dehiscence of pods, since temperature is an essential component of relative humidity. This could not, however, be amply demonstrated.

Seed yields at successive dates of harvest in 1953 ranged from 78 pounds per acre at the earliest date to 32 pounds

Table 3.—Pod development, seed yields, seed weight and germination of birdsfoot trefoil harvested at successive dates in 1953.

Date harvested	Estimated percentages of pod development							Seed yield (Lb./A)	Weight per 1000 seeds (grams)	Percentage of		
	Bloom	Im-mature	Green	Light brown	Dark brown	Black	De-hisced			Germi-nation	Hard seeds	Probable live seeds
July 8	4	31	65	Tr.	0	0	0	77.9	0.732	43	20	63
July 11	2	12	64	14	3	0	5	76.5	0.768	54	18	72
July 14	Tr.	5	18	57	14	0	6	98.5	0.870	56	20	76
July 17	0	Tr.	3	20	61	2	14	83.2	0.888	60	17	77
July 20	0	0	0	3	45	14	38	59.7	0.830	62	16	78
July 23	0	0	0	0	12	17	71	32.0	0.830	59	21	80
Allowance	—	—	—	—	—	—	—	14.5	.083	—	—	8

per acre at the latest date. Differences were highly significant. Since the initial harvests in 1953 were made at a very immature stage (table 3) and subsequent harvests progressed to mature stands, the difference in seed weight was highly significant.

In general, the 1952 and 1953 data both indicate that germination percentage increased as seed matured (tables 2 and 3). Seed weight was dependent upon maturity, as evidenced in the 1953 data which covered a wider range of harvest dates.

Birdsfoot trefoil has a very indefinite flowering and ripening habit as indicated in data in tables 2 and 3. This makes the selection of the proper choice of harvesting date difficult. The previous experiments strongly indicated that between 24 to 27 days following full bloom when pods are light green to light brown would be the optimum time to harvest seed for maximum yields with less risk to pod dehiscence.

Date of Bloom in Relation to Pod and Seed Setting

One hundred umbels, having light brown pods, were harvested from the borders of each of the plots harvested at successive dates in the previous two experiments to study the relationship between date of bloom, number of pods per umbel and number of seeds per pod. Samples were obtained from all harvest dates in 1952 but only at 3 dates in 1953, due to severe drought causing rapid ripening of the 1953 seed crop (table 4).

Early set umbels in both 1952 and 1953 had significantly higher number of pods per umbel (table 4). In 1952, the differences in number of seeds per pod were highly significant with the early set pods containing the higher amount of seed. The number of seeds per pod in 1953 was not different in either date of harvest. This likely was due to the limited number of harvests covering only the early set umbels.

DISCUSSION

Morphological maturity of birdsfoot trefoil seeds previously had not been reported, but many writers have suggested the proper time to harvest birdsfoot trefoil for seed by describing the pod color. Most writers agreed that seed should be harvested when the majority of the pods were dark brown to even black. The data presented in this research indicate that harvesting can and should be done at an earlier stage of development. Since low relative humidity caused pod dehiscence, regardless of whether the herbage was standing or mowed and curing, it is apparent that earlier harvests are essential. It was observed that

Table 4.—Number of pods per umbel and number of seeds per pod from light brown pods at successive dates of harvest in 1952 and 1953.

1952			1953		
Date harvested	Number pods/umbel	Number seeds/pod	Date harvested	Number pods/umbel	Number seeds/pod
July 13	4.30	13.45	July 11	3.56	12.18
July 15	3.97	14.48	July 14	3.36	11.94
July 17	3.18	12.21	July 17	2.56	11.50
July 19	2.78	10.66			
July 21	2.40	8.04			
Allowance	.52	.64		.08	1.04

pods did not dehisce greatly until they turned brown in color. Light green pods contained well developed, nearly mature seeds and these pods resisted dehiscing longer than brown pods. All data seemed to substantiate the hypothesis that it is not necessary to delay harvest until the pods are fully ripe to obtain high quality seed.

Because birdsfoot trefoil has an indefinite flowering habit, it also has an indefinite ripening habit. Determination of a definite harvest time is very difficult. These studies indicated that early set pods produced higher seed yields than late seed pods. Since light green and light brown pods produce high quality seed, these data also would substantiate the desirability of early harvests.

A well controlled experiment involving pods of various colors in the nearly mature to mature range is needed to determine the temperature and relative humidity relationship involved in dehiscence of pods. Under normal climatic conditions of the semi-arid and sub-humid adaptation area of birdsfoot trefoil, it is possible that seed production often would be low due to frequent periods of low relative humidity.

Birdsfoot trefoil normally contains a high percentage of hard seeds, especially from dehisced pods. During combining, and perhaps other handling, some seed coat damage occurs thus reducing the need for scarification. Many farmers who do not have their seed scarified still report satisfactory stands, indicating that hard seeds are not as great a problem as previously thought.

SUMMARY

Birdsfoot trefoil is known to set abundant seed; however, the seed pods dehisce freely upon ripening, and seed losses may be very large. In addition, indefinite flowering

and maturity make it difficult to judge the proper time to harvest.

The objective of this investigation was to study some of the basic factors in seed and pod development as related to stage of maturity to harvest for maximum seed yields. From the analysis of the data presented the following results were found:

1. Pod development was rapid until the 15th day after full bloom with maximum length attained within 21 days.

2. Definite changes in pod color were noted in maturation of pods and seeds. Pods were first a waxy, deep green color, changed to purple color about 1 week following full bloom, and to dark green color soon after the 15th day. Watery, light green pods were noted between 22 and 24 days after full bloom, in 3 to 4 additional days the pods were light brown, and in subsequent 4-day intervals pods were dark brown to black, respectively.

3. Seeds attained morphological maturity within 27 days following full bloom. At this time the pods were light brown in color.

4. Seeds from light green, light brown, dark brown, and black pods were of high quality in regard to germination and seed size. Seeds from dark green pods were immature, were lower in viability and in seed weight than pods more advanced in maturity. Light green pods, although not morphologically mature, produced seed of nearly similar size and quality as more advanced stages and did not dehisce as freely under drying conditions.

5. Umbels set early in the season produced more pods and usually more seeds per pod than umbels set later in the season.

6. Seeds ripened on the plant have a very high percentage of hard seeds. Hard seed content was greatly reduced in threshing and by scarification.

7. Seed losses due to dehiscence of ripe pods either prior to harvest or in mowed and curing herbage were high if relative humidity dropped to approximately 40% and less.

From the results of this study, it may be concluded that higher seed yields may be obtained if birdsfoot trefoil is harvested when the maximum number of pods are light green to light brown rather than at a later stage of maturity. At this stage pods will not shatter as profusely as at more mature stages.

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Inbreeding and Selection of Self-Fertilized Lines of Red Clover, *Trifolium pratense*[1]

H. L. Thomas[2]

THIS paper reports results of 3 years of inbreeding work with red clover to investigate the feasibility of developing inbred lines and selecting among and within them. Many early workers believed red clover was practically self-sterile. However, Fergus (1) in 1922 suggested that perhaps some self-fertile lines existed in the species. In 1921 he artificially self pollinated 650 individual heads, each on a separate plant. Thirty-two heads produced seed ranging in number from 1 to 24 with an average of 0.24 seeds per plant for all 650 bagged. Many abnormalities were found among the seedlings and many seeds failed to produce viable plants. Seventy-nine S_1 plants were self pollinated in 1922, when 463 covered heads produced 1,034 seeds or 2.2 seeds per head.

Kirk (2) in 1925 obtained results similar to those of Fergus. In the summer of 1923 he bagged 430 heads, each on a separate plant and obtained 1,334 seeds or an average of 3.2 seeds per plant. In the progeny he found chlorophyll-deficient seedlings, and the plants which survived were less vigorous and less variable than open-pollinated seed of the same varieties. Both Kirk and Fergus found that bagged heads must be rolled between the fingers to induce pollination. Kirk suggested the application of breeding methods for red clover similar to those employed for maize.

The classical work of R. D. Williams, who published several excellent papers on red clover during the 1930's (4, 5, and others), showed that self sterility in red clover was conditioned by a series of 30 or more oppositional alleles. Another allele in the series designated S_f renders a plant completely self-fertile when the S_f gene is in the homozygous condition. Moreover plants which have the genetic makeup for self sterility sometimes produce a few seeds when bagged, especially if rolled in the early bloom stage. Williams and his co-workers demonstrated heterosis in the species and carried out rather extensive genetic studies establishing several linkage groups.

[1] Contribution from the Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, Minn. Paper No. 3347, Scientific Journal Series, Minnesota Agr. Exp. Sta. Received May 20, 1955.

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Table 1.—Selfed seed obtained from Medium red clover shown by generations with families classified into five groups for average number of seed per plant for the three years.

Class range	S_0 1952			S_1 1953			S_2 1954			Three year total		
	Number plants bagged	Total seed obtained	Seed per plant	Number plants bagged	Total seed obtained	Seed per plant	Number plants bagged	Total seed obtained	Seed per plant	Number plants bagged	Total seed obtained	Seed per plant
0	34	0	0	—	—	—	—	—	—	—	—	—
1–7	261	1938	7.4	408	834	2.0	199	633	3.2	868	3405	3.9
8–14	49	1046	21.3	110	532	4.8	118	1178	10.0	277	2756	9.9
15–21	11	383	34.8	36	305	8.4	75	1289	17.1	122	1977	16.2
22–28	3	120	40.0	3	84	28.0	5	59	11.8	11	263	23.9
29+	6	452	75.3	30	1146	38.2	145	4042	27.9	181	5640	31.2
Total	364	3939	10.8	587	2901	4.9	542	7201	13.2	1493	14041	9.4

Rinke and Johnson (3) in 1941 investigated selfing of red clover and maintained 1 line for 10 generations of selfing after it appeared to be homozygous for the S_f gene. They suggested selection of superior self-fertile lines which would be crossed to remove the S_f gene before use of the lines in synthetics.

METHODS

In 1952, selfing of red clover was attempted on 364 plants at the Rosemount station of the Minnesota Experiment Station. When plants were about to bloom, several branches containing approximately 12 to 15 heads were enclosed in 6½ by 12 inch cotton bags with a weight of 5.9 yards per pound. These were supported by bamboo stakes. Any heads with flowers approaching full bloom were removed. As blooming progressed, the heads were rolled between thumb and fingers without removing the bags. Each plant was treated in this way from 2 to 4 times at intervals varying from 3 to 7 days apart.

The selfed seed obtained was threshed, the S_1 seedlings were started in the greenhouse, and then transplanted to the field in the spring of 1953. The same bagging methods were employed in 1953 and again on the S_2 plants in 1954. In each year the plants were grown in individual plant nurseries in rows 36 inches apart with plants 1 foot apart in the row. In 1953 and 1954, all the progenies of each selfed plant from the year before were grown together in a single plot without replication.

In 1954 a few plants from open-pollinated seed of the S_1 mother plant were grown adjacent to each S_2 line.

Before planting in 1952, open-pollinated seed of three varieties, Wegener, Midland, and Wisconsin Mildew Resistant, were each given X-ray treatments at 3 levels, i.e., 15,000, 30,000, and 45,000 r units. The X-ray treatments were applied at Missouri under the direction of the late L. J. Stadler. The material was planted in 4 randomized blocks with 12 treatments per block (3 levels of X-ray and an untreated check for each variety). Rows or plots consisted of 36 individual plants 1 foot apart and were at 36-inch intervals. Another nursery in 1952 adjacent to the one described previously, consisted of 6 replications of 7 varieties, Midland, Kenland Breeder's Seed, Wisconsin Mildew Resistant, Minnesota Commercial, Ottawa, Dollard, and Wegener. The same spacing arrangement was used and no X-ray treatments were applied.

RESULTS

The term family is used to mean all the self-pollinated progeny of a single 1952 S_0 plant. The 364 families were divided into 5 groups based on the average selfed seed obtained per plant over the three generations S_0, S_1 and S_2. The amounts of selfed seed obtained are presented in table 1.

Average number of seed per plant is reasonably large, ranging from 10 to 30 for 69 of the 364 families.

Out of 364 S_0 plants bagged in 1952 (see table 2), 34 produced no selfed seed and these, of course, were not

Table 2.—Families classified according to selfed seed obtained from S_0 plants and showing how many families were carried into S_1 and S_2 generations.

S_0 1952		S_1 1953		S_2 1954	
Class*	Frequency	Frequency	% of S_0 continued in S_1	Frequency	% of S_0 continued in S_2
0	34	—	—	—	—
1–7	209	83	40.	19	0.6
8–14	47	26	55.	13	28.
15–21	27	25	92.	20	74.
22–28	14	13	93.	8	57.
29+	33	32	97.	25	75.
Total	364	189	52.	85	23.

* By number of selfed seeds.

continued. Among the others, about 50% were lost because selfed seed were few in number, or because seedlings were weak and susceptible to damping off in the greenhouse. Where there were 15 or more selfed seed, about 90% of the lines were continued into S_1. A similar relationship existed between S_1 and S_2, except that a larger proportion of the lines were lost.

To be sure, there may be some accidental cross-pollinated seed among these plants and it is impossible to say how many. However, in each of the years a considerable number of white and yellow seedlings were observed among the selfed progeny. Further evidence for self-fertilization is shown by the average reduction in vigor of the S_2 lines. In table 3 the vigor of 22 S_2 lines is shown in comparison with that of open-pollinated seed of the S_1 mother plant for each line. Rated on a scale of 1 to 5, with 1 most vigorous, the average vigor of the S_2's was 2.8 and the comparable figure for open-pollinated 1.4. In only 3 cases was the inbred line more vigorous than outcrossed seed of the S_1 parent. The variance between S_2 inbred lines was 31.69 while that between open-pollinated S_1 families was only 5.09. Variance within lines was slightly greater for the inbreds than for the open pollinated.

There were some good combiners from each of the varieties represented and apparently, for this sample of lines, there is very little correlation between selfed lines and outcrosses in estimated vigor.

Selfing was carried on in a similar manner on the X-rayed material and the checks, and it appears that the X-ray treatments had no effect on self-fertility. The relation between X-ray treatment and self-fertility class was studied

by means of X^2 for independence. The value obtained was 16.32 which is close to the probability of 0.20, not indicating any effect of X-ray treatment on self-fertility. Three chimera plants were observed in the S_0 generation but other than that there was no evidence of X-ray effects.

In every variety where 50 or more S_0 plants were bagged several self-fertile families were found. So that it would appear from this preliminary evidence that relatively self-fertile lines may be found in all the varieties.

DISCUSSION

From the amounts of selfed seed obtained, it would seem feasible to use the "hybrid corn" method of breeding medium red clover. The advantage gained, of course, would be that selection among self-fertilized lines would be more precise than among more heterozygous material. Probably the genotypes of desirable parents could be maintained more easily from selfed seed than by clones (although there is one clone at the Minnesota station which has lived in the field for 5 years without going through a seed generation).

It is to be hoped that lines may be found that will exhibit heterosis when crossed together and that these might be used in single crosses, double crosses, or several other ways. Williams (4) states that when self-fertile plants are allowed to open-pollinate, approximately half of the seed produced will be crossed. Therefore, two self-fertile inbreds grown in isolation could be expected to produce seed which was about half hybrid and the remainder selfed. Clover seed planted at 8 pounds per acre may produce over 300 seedlings per square yard and, provided the hybrids were distinctly superior in vigor, the established stand might be mostly hybrid.

Williams showed that there were 30 or more alleles in the self fertility series. It would seem reasonable that some of these are more effective in retarding pollen tube growth than others. These intermediate types, when grown in isolation with a different line, should produce seed that was more than half hybrid. Such lines might be relatively self-fertile and, if so, could be rather easily maintained.

SUMMARY

By using large cotton bags and covering several branches of red clover plants, satisfactory amounts of self-pollinated seed were obtained. Flowers were rolled between the fingers 2 or 3 times during the blooming season. It appeared that plants with somewhat higher self fertility could be obtained from any variety if 50 or more plants were treated in this way. It is suggested that selection within self-fertilized lines and their combination to obtain hybrid vigor may be useful in red clover. If gains comparable to those which have been made in corn can be achieved, the value to practical agriculture will be large indeed.

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Table 3.—Comparison of vigor ratings between 22 S_2 lines of red clover with paired plots of open-pollinated seed from S_1 parents of each line. Ratings on a scale of 1 to 5, with 1 the most vigorous; taken on August 18, 1954.

Variety	1954 culture number	S_2 lines							Open-pollinated seed of S_1 parent						
		1	2	3	4	5	Total plants	Avg. vigor	1	2	3	4	5	Total plants	Avg. vigor
Midland	4	5	3	3	—	—	11	1.8	5	—	1	—	—	6	1.3
Midland	60	21	1	—	—	—	22	1.0	6	1	—	—	—	7	1.1
Midland	284	3	6	9	2	1	21	2.6	25	2	—	—	—	27	1.1
Wisconsin Mildew Resistant	28	—	2	13	30	55	100	4.4	—	1	2	—	2	5	3.6
Wisconsin Mildew Resistant	43	—	1	5	2	10	18	4.2	8	1	5	8	4	26	3.0
Wisconsin Mildew Resistant	45	9	—	1	—	—	10	1.2	6	1	—	1	—	8	1.5
Wisconsin Mildew Resistant	46	8	3	—	1	—	12	1.5	2	1	—	—	—	3	1.3
Wisconsin Mildew Resistant	66	10	5	1	—	—	16	1.4	21	7	7	1	—	36	1.7
Wisconsin Mildew Resistant	197	—	1	6	6	1	14	3.5	15	—	—	—	—	15	1.0
Wisconsin Mildew Resistant	205	3	4	9	2	4	22	3.0	10	1	1	—	—	12	1.2
Wisconsin Mildew Resistant	206	1	2	5	4	4	16	3.6	14	1	—	—	—	15	1.1
Wisconsin Mildew Resistant	209	3	5	6	11	5	30	3.3	11	5	1	—	—	17	1.4
Wegener	84	8	1	1	—	—	10	1.3	11	1	—	—	—	12	1.1
Wegener	165	8	1	1	—	—	10	1.3	22	1	—	—	1	24	1.2
Ottawa	175	9	—	1	—	—	10	1.2	15	1	1	—	—	17	1.2
Ottawa	177	8	3	—	2	1	14	1.7	20	4	—	1	—	25	1.3
Minnesota Commercial	263	—	3	5	2	—	10	2.9	6	1	—	—	—	7	1.1
Minnesota Commercial	267	—	—	2	8	4	14	4.1	6	3	1	—	—	10	1.5
Kenland	336	16	9	1	—	—	26	1.4	19	1	—	—	—	20	1.1
Kenland	338	10	2	1	—	1	14	1.6	10	1	—	—	—	11	1.1
Kenland	342	1	4	3	—	2	10	2.8	21	2	1	—	—	24	1.2
Kenland	348	12	—	—	1	1	14	1.5	12	4	—	—	—	16	1.2
Total		135	56	73	71	89	424	2.8	265	40	20	11	7	343	1.4

	d.f.	m.s.	F		d.f.	m.s.	F
Among S_2 lines	21	31.69	38.0	Among open-pollinated S_1 progeny	21	5.09	9.84**
Within lines	402	.83		Within progeny	321	.52	

Rate of Water Entry Into an Irrigated Chestnut Soil as Affected by 39 Years of Cropping and Manurial Practices[1]

A. P. Mazurak, H. R. Cosper, and H. F. Rhoades[2]

CROP production on Tripp very fine sandy loam at the Scottsbluff (Nebr.) Experiment Station was influenced materially by different cropping and manurial practices (2, 3, 8, 9). Kubota, *et al.* (4) presented chemical data indicating appreciable variations in nitrogen, organic matter, soluble phosphorus, and exchangeable potassium contents of Tripp soil as a result of different cropping and manurial practices for a period of 30 years. The physical properties of soil, such as susceptibility of the soil to wind erosion, the amount of water-stable aggregates, and the rate of water entry into the soil were determined after 39 years of cropping. Marked differences in the susceptibility of soil to wind erosion and in the amount of water-stable aggregates were reported previously (5, 6). Differences in rate of water entry into the soil due to cropping and fertilization history are reported here.

PROCEDURE

Rotation plots.—Detailed descriptions of the rotations and the cultural practices used at the Scottsbluff Experiment Station during the period from 1912 to 1941 have been reported (3). The land for the rotation experiments was broken from native sod in the fall of 1910 and was planted to oats during 1911. The soil, Tripp very fine sandy loam, is a Chestnut soil developed from silty or slightly sandy deposits on stream terraces. It is highly productive under irrigation with proper management practices. The number of plots included in any one rotation was determined by the length of rotation, each crop being grown annually on one of the plots. There was no replication.

Most of the rotations were discontinued in 1949, except those used for studying the influence of cropping and manurial practices on the rate of water entry into the soil, and other properties. The cropping sequence and manurial history are given in table 1.

Determination of rate of water entry into soil.—The rate of water entry was measured in each ¼-acre plot at 3 random locations early in the 1950 growing season prior to the first irrigation. Since no special preparation of the soil surface was made, the measurements reflect the soil condition for the previous season plus cultural practices employed for the current seasons. Measurements were started on those plots in which the crop was showing the most distress due to lack of moisture. The sequence of plots was barley, sugar beets, corn, potatoes, and alfalfa. In this sequence it was believed that the crop would have used most of the available moisture by the time measurements were made.

A 2-ring infiltrometer with an inner ring 11.9 inches in diameter and an outer ring of 32.0 inches was used to measure water entry into the soil. The inner ring was driven 4 inches into the soil and the outer ring, 3 inches. A constant 4-inch head of water was maintained in both rings.

Determination of bulk density and moisture constants.—Immediately after the disappearance of water from the soil surface, the site was covered to prevent evaporation. After 48 hours, soil samples to a depth of 5 feet within the inside ring were taken with a Veihmeyer–King tube in increments of 6 inches. The mass and volume of soil for bulk density were corrected for particles >2.0 mm. in diameter and for large roots.

[1] Contribution from the Scottsbluff Experiment Station, Mitchell, Nebr.; the Department of Agronomy, Lincoln, Nebr.; and the Soil and Water Conservation Research Branch, A.R.S., U.S.D.A. Published with the approval of the Director as Paper No. 676, Journal Series, Nebraska Agr. Exp. Sta. Received May 26, 1955.

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Moisture contents from the bulk density samples for each 6-inch increments are expressed on the basis of the mass of soil particles <2.0 mm. in diameter. They represent the field moisture capacity. Values for moisture equivalents and moisture contents at 1/3 and 15 atmospheres were also determined on these samples which were air-dried.

Determination of $CaCO_3$.—Soil samples for $CaCO_3$ determinations were taken from an adjoining area. Each site was sampled by 3-inch increments to a depth of 5 feet. Calcium carbonate content was determined by adding an excess amount of 1 *N* HCl to a known amount of soil and back titrating with 1 *N* NaOH.

RESULTS

As shown in tables 2 and 3, high rates of water entry occurred at early application and diminished rapidly by the end of 30 minutes, reaching an asymptotic value by 90 minutes. The greatest differences in rates of water entry were found with the continuous cropping systems. The highest rates were on plots cropped to alfalfa; the lowest on plots cropped to corn. Rates were nearly identical for plots cropped continuously to potatoes or to barley. The rates obtained for the continuous non-manured alfalfa plot at the end of 10 and 120 minutes were 37.9 and 30.6 cm. per hour, respectively, whereas the corresponding rates

Table 1.—Crop rotations at the Scottsbluff (Nebr.) Experiment Station selected to study the influence of cropping and manurial practices on the rate of water entry into Tripp soil.

Number of rotation		Crop sequence and fertilizer for period after 1941
From 1912 to 1941	After 1941	
		Continuous cropping
8	8	Alfalfa
—	8B*	(M) alfalfa§
4	4	Potatoes
—	4B*	(M) potatoes
1	7	Barley
—	7B*	(M) barley
6	6	Corn
—	6B*	(M) corn
		2-year rotation
20	20	Sugar beets, potatoes
21	21	(M) sugar beets, potatoes
		3-year rotation
30	35†	Sugar beets, barley, potatoes
31	35B†	(M) sugar beets, barley, potatoes
		4-year rotation
40	41‡	Barley (alfalfa), alfalfa, potatoes, sugar beets
		6-year rotation
60	63‡	Barley (alfalfa), alfalfa 3 yrs., potatoes, sugarbeets
61	63B†‡	Barley (alfalfa), alfalfa 3 yrs., potatoes, (M) sugar beets

* One-half of original ¼ acre plot manured each year starting in 1942.
† Barley substituted for oats beginning in 1942.
‡ Barley used as a companion crop with alfalfa beginning in 1942; alfalfa was seeded alone prior to 1942.
§ (M) = 12 tons manure per acre applied for the crop indicated.

obtained on the continuous corn plots were 7.5 and 0.50 cm. per hour.

Marked differences in the rates of water entry were obtained between manured and non-manured plots in the same rotation. The influence of manure on the rates of water entry into soil is best illustrated in the continuous cropping systems. It is probably associated directly with its presence, since the cultural operation with each crop in question is the same in both manured and non-manured plots. The rate of water entry was nearly twice as great for the manured plots planted continuously to potatoes, barley and corn as that for similar non-manured plots. The difference in the continuous manured alfalfa plot in contrast with the non-manured alfalfa plot was only a fraction as large.

Rate of water entry for the 6-year rotation cropped to first year alfalfa in 1950 was higher than the rates for the second or third year alfalfa plots (table 2). The highest rate was on a plot cropped to potatoes in 1950 which was cropped to third year alfalfa in 1949. This high rate of water entry into soil was undoubtedly due to 3 previous years of alfalfa rather than to the effect of cropping to potatoes early in 1950. On the other hand, a low water intake rate was obtained for the plot planted to sugar beets in 1950 which was cropped to potatoes in 1949. The intensive cultural operations required for potatoes were still reflected by the low intake rates during the next season when cropped to sugar beets. A more receptive surface conditon for water was observed on the plot in first year of alfalfa in 1950 which had been cropped to barley in 1949. After 1 year of alfalfa, the receptiveness of the surface soil began to decrease as shown by the lower rate on the plot cropped to second year alfalfa in 1950. After 3 years of alfalfa the rate of water entry into the soil increased.

These data support the thesis that continuous cropping of row crops has a deteriorating effect on soil structure. Water intake measurements are used here to evaluate the overall effects of cropping and manurial practices on soil physical properties. Continuous corn caused a greater deterioration of soil structure than continuous potatoes. That manure maintains stable soil structure is supported by the data in tables 2 and 3 when the ratio of water intake rates at 10-minutes to that at 120-minutes is calculated. The higher the ratio, the lower is the water-stability of aggregates. The ratio is 15 for continuous corn without manure, whereas for manured corn, it is 2.4. For purpose of comparison, the most stable soil structure is that for the continuous alfalfa which has a ratio between 1.2 and 1.5.

Alfalfa in crop rotation aids materially in maintaining good soil structure as judged by the ratios of water intake. The average ratios for the 2-, 3-, 4-, and 6-year rotations, without manure, are 5.3, 3.6, 2.3, and 2.7 respectively. It is of interest to note that the 4-year rotation has lower ratios for each crop than those for crops in 6-year rotation.

Other Factors Associated With Rates of Water Intake

Calcium carbonate contents.—Concentrations of $CaCO_3$ in 5-foot soil profiles varied within a given plot, as well as from plot to plot. A portion of the data is shown in figure 1. Lines of equal $CaCO_3$ content are shown for 5-foot profiles across the length of field for Series II. For

Table 2.—Effect of crop rotation on the rate of water entry into a Tripp very fine sandy loam. The values for the rates are averages of three determinations except where otherwise noted.

Cropping practice in:		Rate of water entry, cm. per hour, at:					Ratio of water entry 10-min. / 120-min.†
1949	1950	10 minutes	30 minutes	60 minutes	90 minutes	120 minutes	
		Continuous cropping					
Alfalfa	Alfalfa*	37.9	32.3	30.7	30.6	30.6	1.2
Potatoes	Potatoes	12.3 ±2.65	7.2 ±1.85	3.9 ±0.40	3.4 ±0.01	3.4 ±0.01	3.6
Barley	Barley	12.0 ±4.55	4.9 ±0.90	4.1 ±1.20	4.1 ±1.15	4.1 ±1.15	2.9
Corn	Corn*	7.5	2.0	0.6	0.50	0.50	15.0
		2-year rotation					
Potatoes	Sugar beets	Plots not available for measurement					
Sugar beets	Potatoes	11.2 ±0.89	3.3 ±0.78	2.2 ±0.47	2.2 ±0.47	2.1 ±0.47	5.3
		3-year rotation					
Corn	Sugar beets	6.5 ±0.49	2.6 ±0.45	1.8 ±0.53	1.9 ±0.51	1.9 ±0.51	3.4
Sugar beets	Barley*	8.5	3.3	2.5	2.3	2.1	4.0
Barley	Potatoes	18.3 ±2.15	8.0 ±0.87	5.6 ±0.95	5.4 ±0.94	5.4 ±0.94	3.4
		4-year rotation					
Sugar beets	Barley*	15.0	9.8	9.0	9.0	9.0	1.7
Barley	Alfalfa	19.7 ±3.48	13.3 ±3.50	12.0 ±2.67	11.2 ±2.07	11.2 ±2.07	1.8
Alfalfa	Potatoes	15.4 ±1.25	6.5 ±0.41	5.1 ±0.10	5.1 ±0.14	5.1 ±0.14	3.0
Potatoes	Sugar beets	12.4 ±0.005	5.8 ±0.70	4.5 ±0.50	4.5 ±0.50	4.5 ±0.50	2.8
		6-year rotation					
Sugar beets	Barley*	16.5	7.1	6.1	5.8	5.8	2.8
Barley	1-yr. alfalfa	18.1 ±3.08	11.0 ±1.73	9.6 ±0.88	9.0 ±0.64	8.7 ±0.44	2.1
1-yr. alfalfa	2-yr. alfalfa	13.9 ±1.94	6.7 ±1.52	5.4 ±1.50	5.0 ±1.40	4.8 ±1.24	2.9
2-yr. alfalfa	3-yr. alfalfa	14.4 ±2.45	7.1 ±0.81	6.5 ±0.82	6.3 ±0.85	6.3 ±0.85	2.3
3-yr. alfalfa	Potatoes	33.4 ±4.68	16.8 ±3.91	16.2 ±3.68	16.2 ±3.68	16.2 ±3.68	2.1
Potatoes	Sugar beets	5.2 ±0.80	1.5 ±0.55	1.3 ±0.40	1.3 ±0.40	1.3 ±0.40	4.0

* Single determination.
† Asymptotic values were actually used.

Table 3.—Effect of manure and crop rotation on the rate of water entry into a Tripp very fine sandy loam. The values for the rates are averages of three determinations except where otherwise noted.

Cropping practice in:		Rate of water entry, cm. per hour at the end of:					Ratio of water entry 10-min.
1949	1950	10 minutes	30 minutes	60 minutes	90 minutes	120 minutes	120-min.†
				Continuous cropping—manured			
Alfalfa	Alfalfa	55.2±1.20	42.3±3.21	38.2±3.28	37.0±3.67	37.0±3.67	1.5
Potatoes	Potatoes	26.5±3.50	16.0±0.60	12.1±0.90	11.1±0.90	11.1±0.90	2.4
Barley	Barley*	24.4	12.4	9.6	9.5	9.4	2.6
Corn	Corn	16.0±1.00	8.9±0.95	7.5±1.55	6.9±1.90	6.8±2.05	2.4
				2-year rotation—manured			
Sugar beets	Sugar beets	14.1±2.31	8.7±1.85	6.4±1.73	6.4±1.73	6.3±1.71	2.2
Potatoes	Potatoes	17.2±5.07	10.1±3.07	8.2±2.55	8.0±2.46	8.0±2.46	2.2
				3-year rotation—manured			
Corn	Sugar beets	14.5±1.61	7.4±1.47	5.7±1.28	5.2±1.27	5.2±1.27	2.8
Sugar beets	Barley*	16.5	9.0	6.2	5.6	5.5	3.0
Barley	Potatoes	17.0±0.76	8.0±1.48	5.7±1.39	5.4±1.21	5.4±1.21	3.1
				6-year rotation—manured			
Sugar beets	Barley*	21.0	9.5	7.4	7.4	7.4	2.8
Barley	1-yr. alfalfa	19.4±5.60	7.4±0.20	6.3±0.10	6.4±0.07	6.4±0.07	3.0
1-yr. alfalfa	2-yr. alfalfa	11.7±3.53	7.3±2.65	6.3±2.59	4.1±0.98	4.0±1.03	2.9
2-yr. alfalfa	3-yr. alfalfa	20.7±3.69	13.0±2.55	10.1±1.92	9.8±1.83	9.7±1.75	2.1
3-yr. alfalfa	Potatoes	36.7±2.83	28.7±2.29	24.1±3.03	22.5±2.95	23.5±2.92	1.6
Potatoes	Sugar beets	19.1±0.95	12.2±0.35	9.0±0.35	8.8±0.25	8.8±0.25	2.2

* Single determination.
† Asymptotic values were actually used.

the field as a whole, $CaCO_3$ is concentrated nearer the surface at the upper end of the field (Tier 16, 17 and 18). This is probably due to the original soil profile rather than due to cropping history. The two extreme lower depths of $CaCO_3$ concentration occurring in Tier 10 and 13 through 15 is probably due to the leaching action of excess irrigation water. In the past, the excess irrigation water has tended to accumulate in these two areas.

From inspection of data on the $CaCO_3$ contents of 5-foot soil profiles, it appears that the addition of manure had increased the depth to the $CaCO_3$ concentration. The lowering of depth to the $CaCO_3$ is only an inference, as no measurement is available for the depth of $CaCO_3$ or the amount present before the rotations were begun. However, in figure 1, the effect of the addition of manure in lowering the depth of $CaCO_3$ concentration is shown clearly in Tier I cropped continuously to potatoes.

Calcium carbonate in its free state may occupy spaces between soil particles, thereby, decreasing the available space for transmitting water. To check this factor on water intake rates, a linear correlation was calculated between the asymptotic rate of water entry, cm. per hour, and the percent of $CaCO_3$ in the 5-foot profile. The correlation coefficient was not significant, $r = 0.11$. Hence it appears that $CaCO_3$ in the 5-foot profile was not the limiting factor in water intake.

Textural profile.—A previous report (4) indicated that the percentage of particles $<2\mu$ in diameter in the surface 12 inches was rather uniform throughout the rotation. However, the data for moisture contents at tensions of 1/3 and 15 atmospheres, at field moisture capacities and moisture equivalents indicate textural variation from plot to plot[3], especially at the lower depths. Individual determinations of samples by 6-inch depths were summarized for 5-foot profile depths. The values for 1/3 atmospheres range from 10.6 to 22.1%. The field moisture capacities reflected the same magnitudes from 12.7 to 20.9% and the moisture equivalents from 11.9 to 21.1%. Moisture percentages at tensions of 15 atmosphere for the 5-foot profiles ranged from 6.1 to 10.8.

Correlation coefficients between the rates of water intake and the moisture equivalents for the 5-foot profile were calculated to evaluate the effect of textural profile on water intake. No significance was found to be associated with differences in textural profile. Because no difference was found, even though the textural differences were present, it seems evident that the water intake rates were affected more by cropping and manurial practices than by the textural profile for the 5-foot depth.

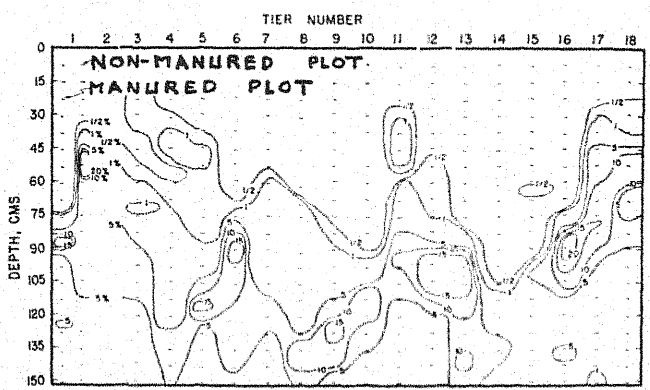

FIG. 1.—Soil profile with lines of equal $CaCO_3$ content across the length of field for Series II. Horizontal lines designate the depths of samples.

[3] Cosper, H. R. Moisture relationships in 39 year old rotation plotes on an irrigated Chestnut soil. M.S. thesis, University of Nebraska. p. 88. 1953.

Bulk density.—Differences in rate of water entry into soil may be associated with differences in bulk density. Accordingly, correlation coefficients were calculated between rates of water entry and bulk densities of the 0 to 10 inch, 10 to 30 inch, and the entire 5-foot profile.

A significant correlation coefficient ($r = -0.35$) between rates of water entry and bulk density for the 0 to 10 inch depths were obtained. Bulk density values for surface horizons ranged from 0.84 (manured plot) to 1.35 g. per cc. The linear regression equation for this relationship was $Y = 47.4 - 24.9X$, where Y is the rate, cm. per hour, of water entering the soil at 10-minute application, and X is the bulk density, g. per cc., for the surface 10 inches. When the data were separated into manured and non-manured plots, the correlation coefficient for the manured plots was not significant, whereas the correlation coefficient was highly significant ($r = -0.56$) for the non-manured plots. In the latter relationship only a relatively small portion of the variability in intake rate can be associated with differences in bulk density.

There was no significant correlation between the final rate of water intake and the bulk density for the entire 5-foot profile. Also there was no significant correlation between bulk density of the 10 to 30 inch depths and the rate of water entry at 30-minute application.

SUMMARY

A constant rate of water entry into Tripp soil was usually obtained after 2 hours of irrigation. The intake of water was influenced by the application of manure and cropping history during a period of 39 years. Maximum rates of water entry after 2 hours of irrigation were obtained in the continuous alfalfa plots; the rates were 30.6 and 37.0 cm. per hour for the non-manured and manured treatments, respectively. The next highest rates of water entry were measured on plots where potatoes were growing, following the plowing under of a 3-year-old stand of alfalfa in a 6-year rotation. The rates after 2 hours of irrigation were 16.2 and 23.5 cm. per hour for the non-manured and manured treatments, respectively. A minimum rate, 0.5 cm. per hour, of water entry into soil after 2 hours of irrigation was obtained for continuous corn. Where manure was applied annually since 1942 to the continuous corn plot, the rate of water entry was 6.8 cm. per hour.

Relationships between a few physical properties of soil and rates of water intake were studied. Linear regression equations were obtained between water intake and bulk densities of horizons, contents of $CaCO_3$, and textural profile as indicated by moisture equivalent, 1/3 and 15 atmospheres. The surface horizon, 0 to 10 inch depth, influenced the rate of water intake but the lower horizons showed no apparent effects. Conclusion was that cropping and manurial practice had more effect on the rates of water intake than did the textural variation within the profile.

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Agronomic Affairs

MEETINGS

Nov. 6–12, International Crop Improvement Association, Winter Haven, Fla.

Dec. 26–21, American Association for the Advancement of Science, Atlanta, Ga.

Jan. 12–14, Conference on the Use of Isotopes in Agriculture, sponsored by the Council of Participating Institutions of the Argonne National Laboratory, Michigan State University, East Lansing.

Jan. 16, Southern Weed Conference, New Orleans, La.

Feb. 15–17, Joint meeting, Western Weed Control Conference and California Weed Conference, Sacramento, Calif.

WESTERN BRANCH NAMES NEW OFFICERS

B. A. KRANTZ of the USDA Western Soil and Water Management Section, Billings, Mont., was named president of the Western Society of Soil Science at the group's annual meeting in Davis, Calif., Aug. 16. He succeeds ROBERT M. HAGAN of the University of California at Davis.

Other society officers named for the coming year are: vice president, DANIEL G. ALDRICH, Jr., University of California, Davis; and secretary-treasurer, C. D. MOODIE, State College of Washington, Pullman, Wash. Dr. Krantz served as vice president and Aldrich as secretary-treasurer during the past year.

Krantz, Aldrich, and Moodie will also serve respectively as president, vice president, and secretary-treasurer of the Western Branch of the American Society of Agronomy during the coming year. Under an organizational arrangement with the Western Society of Crop Science, in which offices in the branch rotate between the two societies in alternate years, these offices were held by the corresponding officers of the crop science group during the 1954–55 year.

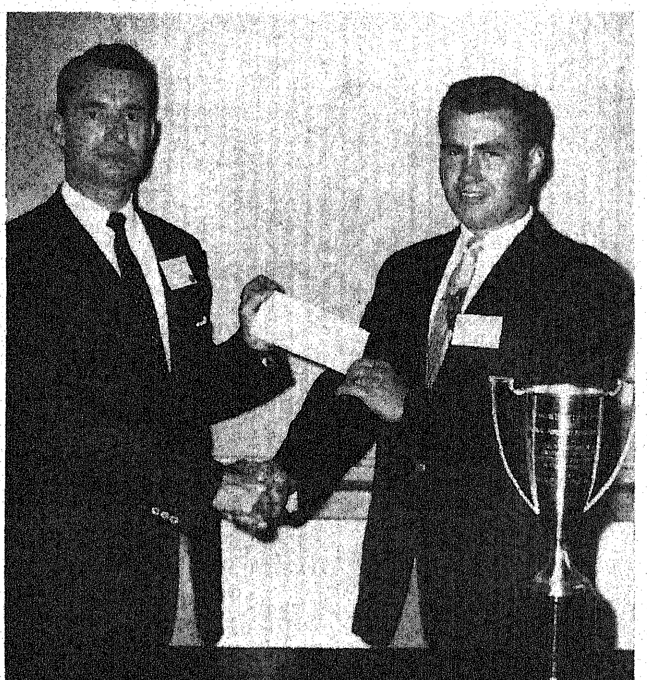
Officers of the Western Society of Crop Science during the past year were: president, DEAN MCALISTER, University of Arizona, Tucson, Ariz; vice president, ROLLO WOODWARD, Utah State Agri-

cultural College, Logan, Utah; and secretary-treasurer, H. M. LAUDE, University of California, Davis. They will continue in office for the coming year.

RUTGERS STATION OBSERVES 75TH ANNIVERSARY

The New Jersey Agricultural Experiment Station observed its 75th anniversary in ceremonies Oct. 6 at Rutgers University, New Brunswick, N. J. At a convocation on that date, the university conferred honorary degrees on EZRA BENSON, U. S. secretary of agriculture; GLENN W. BURTON, USDA, Tifton, Ga., forage grass breeder, who received the Ph.D. degree from Rutgers University in 1936; CHARLES F. SEABROOK, Bridgeton, N. J., and WILLIAM H. W. KOMP, University of Maryland medical entomologist. Other events included the unveiling of a bronze plaque of JACOB GOODALE LIPMAN, third director of the station. Staff members of the station, college of agriculture, and extension service will have an informal dinner on Nov. 8 at which highlights of station history will be presented in dramatic form.

ILLINOIS AGRONOMY CLUB WINS "BEST" AWARD



WILLARD H. GARMAN, left, of the National Plant Food Institute, presents a $100 check and a trophy to DUANE SWARTS, Dixon, Ill., president of the University of Illinois Field and Furrow Club which received the National Agronomy Achievement Award for 1955. The presentation was made at the annual banquet of the American Society of Agronomy Aug. 17 at Davis, Calif. The award designates the Illinois club as the best student agronomy organization of its kind in the United States.

Determination of the award winner each year is made by the Student Section of the American Society of Agronomy on the basis of accomplishment in education, general college activities, fund raising projects, and others. R. M. SWENSON, Michigan State University, 1955 chairman of the Student Section, supervised the contest.

Along with Swarts, seven members of the Field and Furrow Club, which has 75 active undergraduate members, attended the meeting in Davis. Swarts, a senior, lives on a farm near Dixon. He is active in several student organizations, has served as president of the Agricultural Council, and has an outstanding scholatsic record. Other officers are GORDON REICHERT, Farina, vice president; ALAN YUNGBLUTH, Warren, secretary-treasurer; and A. W. MCDONALD, St. Mary's, club reporter. M. B. RUSSELL is faculty advisor for soils, and A. W. BURGER and F. W. SLIFE are advisors for crops.

ROBERT M. SALTER DIES AT 63

ROBERT M. SALTER, chief of soils research for the U. S. Department of Agriculture and former head of the Soil Conservation Service, died Sept. 13 at his home in Silver Spring, Md., at the age of 63.

R. M. Salter

Since November 1953, Dr. Salter had been chief of the Soil and Water Conservation Research Branch of the Agricultural Research Service. He had previously served for 2 years as chief of the Soil Conservation Service, and from 1942 to 1951 he headed the former USDA Bureau of Plant Industry, Soils, and Agricultural Engineering.

Dr. Salter was one of the country's outstanding scientific leaders in research on crops and soils. As a research administrator, Dr. Salter was noted for his sponsorship of the "whole-farm approach" to agricultural research, emphasizing the need for integrated application of new scientific developments to permit faster improvement of the many interdependent phases of farm operations.

A native of Huntington, Ind., Dr. Salter grew up in northwestern Ohio and was graduated from Ohio State University in 1913, where he also received the Master's degree and served as an instructor in agricultural chemistry. From 1915 to 1921 he was soil chemist and agronomist at the West Virginia Agricultural Experiment Station.

Dr. Salter was appointed professor of soils at Ohio State University in 1921, and from 1925 to 1929 was in charge of agronomic research for the Ohio Agricultural Experiment Station. He became chairman of the agronomy department in 1929, and associate director of the experiment station in 1939.

In 1940, Dr. Salter was appointed director of the North Carolina Agricultural Experiment Station, and a year later he joined the U.S.D.A. in Washington, D. C., as head of the Division of Soils and Fertilizer Investigations in the former Bureau of Plant Industry. He became chief of the newly organized B.P.I.S.A.E. in 1942.

Dr. Salter was appointed chief of the Soil Conservation Service in 1951, succeeding H. H. BENNETT. He served 2 years in this post. In November 1953, following his request that he be transferred, for reasons of health, to a position with less arduous responsibilities, Dr. Salter was made chief of the new Soil and Water Conservation Research Branch.

In 1952, Dr. Salter received the U.S.D.A. Distinguished Service Award. Dr. Salter was a fellow and former president of the American Society of Agronomy, a fellow and officer of the American Society for the Advancement of Science, and a member of the National Research Council, Soil Science Society of America, Soil Conservation Society of America, Sigma Xi, Phi Lambda Epsilon, and Gamma Sigma Delta.

He is survived by his wife, Mrs. Sara Godfrey Salter, and their four children, Mrs. Francis T. Phillips, Jr., Omaha, Nebr.; Robert M. Salter, Jr., Pacific Palisades, Calif.; Richard G. Salter, of Cleveland, O.; and Mrs. E. B. Browne, of Athens, Ga.

JENNINGS OF UTAH RETIRES

DAVID STOUT JENNINGS, professor of agronomy at Utah State Agriculture College, has retired after nearly 50 years with the college as a student and teacher. He will continue on the staff as emeritus professor.

Dr. Jennings was born Jan. 1, 1885, in Rockville, Utah. He was graduated from Utah State Agricultural College in 1912, and received the Ph.D. degree in 1917 from Cornell University. After one year as a county agent in Utah, he was employed by the Agricultural Experiment Station to be in charge of soil survey. Most of the arable acres in Utah have been surveyed under his supervision. He is also a teacher of soil genesis, classification, and survey. His primary research has been largely in the field of soil physics and irrigation.

Recently Dr. Jennings conducted a soils investigation in an agricultural development program of two large river valleys in Angola, Africa.

SOUTHERN WEED CONFERENCE MEETS JAN. 16

The ninth annual meeting of the Southern Weed Conference will be held Jan. 16–18 at the Hotel Jung in New Orleans, according to GLENN C. KLINGMAN, president. MARK WEED, of

the DuPont Co., is program committee chairman. Those interested in the program may contact him in care of the Botany Department, Louisiana State University, Baton Rouge.

Other 1956 conference officers are W. B. ALBERT, South Carolina experiment station, Clemson, S. C., vice president; and E. G. RODGERS, University of Florida, Gainesville, secretary-treasurer.

FREDERICK D. RICHEY DIES IN TENNESSEE

FREDERICK D. RICHEY, retired U.S.D.A. principal agronomist in corn investigations, died Sept. 11 at Knoxville, Tenn.

Dr. Richey was born in St. Louis, Mo., Sept. 3, 1884. He received the B.S.A. degree from the University of Missouri in 1909 and his alma mater conferred upon him the D.Sc. in 1949.

Dr. Richey retired in September 1954 after 43 years in corn breeding research, 37 of which he was with the U.S.D.A. in several different capacities. He joined the U.S.D.A. in 1911, and in 1922 was appointed agronomist in charge of corn investigations in the Bureau of Plant Industry. He became associate chief of the bureau in 1933, and chief in 1934, remaining in this capacity until 1938. After several years in private business, Dr. Richey returned to the department in 1943 to coordinate corn breeding in the South, and to head the cooperative corn breeding project at the Tennessee Agricultural Experiment Station.

He received the U.S.D.A. distinguished service award in 1948, in recognition of his "outstanding service in organizing and leading the cooperative corn breeding program which gave hybrid corn to American agriculture".

Dr. Richey was a Fellow of the American Society of Agronomy and served as president of the society in 1937. He was the author of more than 60 publications on corn breeding and research.

ENSIGN IS ASSOCIATE DIRECTOR AT IDAHO

RONALD D. ENSIGN was recently appointed associate director of the Idaho Agricultural Experiment Station at the new station headquarters on the University of Idaho campus, Moscow. He was superintendent of the Aberdeen Branch Experiment Station from 1952 until his appointment last July. Dr. Ensign received the Ph.D. degree in 1952 in plant breeding at Cornell University. He has been in charge of the corn improvement program at the Idaho station.

R. D. Ensign

FIRST CALIFORNIA FORESTRY DEAN DIES

WALTER MULFORD, 78, first dean of the University of California School of Forestry, died Sept. 7 at St. Helena, Calif. A native of Millville, N. J., he was a graduate of the first forestry course given in America at Cornell University. He was the first state forester in America, and built the Connecticut state forestry organization. His teaching career included Yale, Cornell, and Michigan universities following which he became the pioneer of the California forestry school.

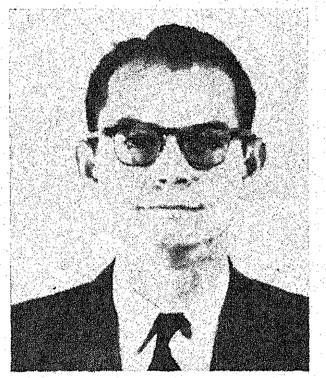
YUGOSLAV SOIL SCIENCE SOCIETY HOLDS FIRST CONGRESS

The first Congress of the Yugoslav Society of Soil Science was held Sept. 19-22 at Portoroz, Slovenia. Meetings of its five commissions (similar to the commissions of the International Society of Soil Science and the divisions of the Soil Science Society of America) held sessions on each of the 3 days of the Congress. Excursions into Slovenia and Croatia were conducted from Sept. 23-27. Chairmen of the five commissions of the society are as follows:

VIKTOR NEJGEBAUER, Faculty of Agriculture, Zagreb, Commission I, soil genesis and classification; G. J. JANEKOVIC, Faculty of Agriculture, Sarajevo, Commission II, soil physics and soil chemistry; Z. TESIC, Faculty of Agriculture, Belgrade, commission III, soil biology; M. JEKIC, Faculty of Agriculture, Skopje, commission IV, soil fertility, plant nutrition, and fertilizers; and L. STOJKOVIC, Faculty of Agriculture, Novi Sad, commission V, soil technology.

COLLINGS SUCCEEDS PITNER AT CLEMSON

Collings



Pitner

GILBEART H. COLLINGS, Sr., has succeeded JOHN B. PITNER as head of the agronomy department at Clemson Agricultural College, Clemson, S. C. Dr. Pitner resigned in August to accept a position as manager of agricultural service for the Grace Chemical Co. He had been with the college since 1954. For the previous 7 years he was soil scientist with the Mexican agricultural program of the Rockefeller Foundation. Dr. Collings, professor of soils, is author of the textbook, "Commercial Fertilizers—Their Sources and Use."

NEWS ITEMS

WALLACE E. HOLMES is now affiliated with the University of Hawaii and the Hawaii Agricultural Experiment Station in the position of assistant professor in soil science and assistant soil scientist. He was formerly a graduate fellow in soils at the University of Wisconsin, where he completed work for the Ph.D. in soil science in July of this year.

—A—

E. V. MILLER, former associate professor of agronomy in soil fertility, North Carolina State College, is now chief agriculturist for Chemicals International Division of Olin Mathieson Chemical Corp., conducting studies of soil conditions and fertilizer requirements in countries served by Olin Mathieson.

—A—

L. R. FREDERICK, assistant microbiologist in the departments of agronomy and botany, and plant pathology at Purdue University, has accepted a position in teaching and research as associate professor of soils in the agronomy department at Iowa State College, Ames. He is in charge of teaching undergraduate soil fertility and soil microbiology, and is also conducting research in soil microbiology.

—A—

JAMES A. VOMOCIL, who completed requirements for the Ph.D. degree from Rutgers University in July, is now instructor in the department of soils and plant nutrition, University of California, Davis.

—A—

STERLING R. OLSEN, senior soil scientist with U.S.D.A. at Fort Collins, Colo., is visiting professor of agronomy (soils) at Iowa State College for the period Sept. 16 through Dec. 16.

—A—

HARRY HUDSON BAILEY, who joined the University of Kentucky staff as an assistant agronomist on July 1, is engaged in work on soil classification and clay mineralogy.

—A—

FRANK A. LOEFFEL was appointed associate agronomist in charge of corn improvement effective Oct. 1, at the University of Kentucky.

—A—

J. B. HARRINGTON, head of the field husbandry department of the University of Saskatchewan, has been granted leave of absence to undertake an assignment for the Food and Agriculture Organization of the United Nations. He will work for FAO as regional advisor on its wheat and barley breeding project in Egypt, Jordon, Lebanon, Syria, Cyprus, Turkey, Iran, Iraq, and Pakistan. Dr. Harrington will be based at FAO Headquarters at Rome and spend about 8 months of the year visiting the various breeding stations of the region.

On Sept. 1, LLOYD C. HULBERT began an appointment as assistant professor in the department of botany and plant pathology at Kansas State College, Manhattan. His work involves teaching courses in plant ecology and plant taxonomy, herbarium work, and research in plant ecology. At the Universtiy of Minnesota, he was an insctructor in botany for 4 years, teaching and conducting research with emphasis on plant ecology.

—A—

HARVEY J. WALKER joined the Texas Agricultural Experiment Station staff Aug. 1 as assistant agronomist at the Lubbock station. He has a bachelor degree from Texas A&M College and an M.S. from Texas Technological College.

—A—

H. LEE SCHWANZ has been named managing editor of *Farm Profit*, published in Milwaukee, Wis., by the Massey–Harris Co. He was formerly with *Country Gentlemen* and *Better Farming*.

—A—

WILLARD SCHMEHL has returned to Colorado A&M College following one year of advanced research at the University of Wisconsin soils department.

—A—

W. RALPH SINGLETON, of the biology department, Brookhaven National Laboratory, Upton, L. I., N. Y., is now Miller Professor of Biology at the University of Virginia. He will also serve as director of the Blandy Experiment Farm, Boyce, Va., during the winter months.

—A—

WAYNE D. ANDERSON has started work at Riverton, Wyo., as a University of Wyoming soils technician and research assistant in agronomy.

—A—

GERALD L. LOWRY, who received the M.S. degree in June 1955 from Oregon State College, is now instructor at the Ohio Agricultural Experiment Station, Wooster. His research there is concerned with coal stripped land reclamation with emphasis on revegetation of spoil banks with forage crops and tree species. He received the B.S. degree in Forestry from Pennsylvania State University in 1953.

—A—

J. H. STOECKLER, forester in charge of the Forest Research Center, Rhinelander, Wis., from 1946–54, is now in charge of forest soil and forest influence investigations at the Lake States Forest Experiment Station, St. Paul, Minn. His work concerns soil-site investigations, watershed management, and shelterbelt investigations.

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JOHN E. BAYLOR, associate extension specialist in farm crops, Rutgers University, was granted a 2-year leave effective Sept. 1 to complete work on the Ph.D. degree in agronomy at Pennsylvania State University. His forage work at Rutgers is being continued currently by C. RICHARD SKOGLEY. At Pennsylvania State, he is engaged in seedling establishment of birdsfoot trefoil.

—A—

Six additional staff members of New Mexico A&M College are now on 2-year assignments with the Agricultural College, University of Sind, at Tando Jam, Pakistan. Among them is EUGENE E. STAFFELDT, assistant plant pathologist. HAROLD E. DREGNE, professor of soils, was in the advance party which left for the south Asia country in July.

—A—

ROBERT H. KING has succeeded O. A. BEATH as head of the University of Wyoming Agricultural Research Chemistry Department.

—A—

WILLIAM F. WATKINS, agriculturist with the Eastern Fertilizer Division of Olin Mathieson Chemical Corporation, has been named agronomist for the Great Lakes sales district with headquarters at Lafayette, Ind.

GLENN A. FEATHER, soil scientist of York, Nebr., is now with the U. S. International Cooperation Administration (former FOA) at Rawalpindi, Punjab, West Pakistan.

—A—

RAY GRESHAM has been named assistant extension soil conservationist at South Dakota State College, replacing LEONARD LADD who is on leave of absence in Jordan.

—A—

RONALD B. FOSTER transferred in September from the University of Arizona agronomy department at Tucson to the University of Idaho Extension Service as the extension agent for Teton County at Driggs, Idaho. He was instructor and assistant agronomist in forage crops research at the University of Arizona.

—A—

At the University of Arkansas entomology department, ROBERT C. HUNTER has replaced JOHN R. BAGBY, Jr., in a research project on cotton bollworm control.

—A—

After 6 years as instructor in soil science at Michigan State University, NATHAN A. WILLITS transferred Sept. 1 to Rutgers University as assistant professor of soil physics. He received the Ph.D. degree at Michigan State.

—A—

FELIX V. JUSKA has been appointed research agronomist with the USDA at Beltsville, Md., where he will be primarily responsible for developing and carrying out investigations in turfgrasses. He received undergraduate and advanced degrees at Michigan State University.

—A—

WALTER M. NIXON returned recently to the Soil Conservation Service at Lincoln, Nebr., from an ICA assignment in Turkey where he participated in a program of training technicians for the Turkish Ministry of Agriculture. The program was devoted to pasture and range management, grass and legume seed production, and management of grasses and legumes for grazing, hay and silage.

—A—

W. H. MITCHELL has returned to the University of Delaware as assistant professor in agronomy after spending the past year on leave at Pennsylvania State University working toward the Ph.D. degree.

—A—

HAROLD GAUSMAN has joined the agronomy staff at the University of Maine as an associate agronomist in soil chemistry and plant nutrition. Dr. Gausman had been at the New Jersey Experiment Station for 1½ years. He replaces Dr. KENNETH NIELSEN who is now senior agronomist with the Canada Department of Agriculture.

—A—

LESTER E. CLAPP, extension soil conservationist at Iowa State College, has been named soil conservation training advisor in Brazil with the State Department ICA. He will be stationed at the Fazenda Ipanema training center in the state of Sao Paulo.

—A—

JEFFERY E. DAWSON has returned to Cornell University as soil science professor following a special assignment with the Soil Conservation Service establishing a new classification system for muck soils.

—A—

BILLY TUCKER, who received the Ph.D. degree at the University of Illinois last summer, is now soil scientist on the staff of the Red Plains Conservation Experiment Station, Guthrie, Okla.

—A—

ELDON L. ZICKER of the University of Wisconsin soils department has moved to Yakima, Wash., where he is now engaged in a family orchard enterprise.

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AGRONOMY JOURNAL

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Willcox's Agrobiology: IV. Review of Willcox's Reply[1]

C. A. Black, O. Kempthorne, and W. C. White[2]

THE July, 1954, issue of *Agronomy Journal* contains a series of three papers,[3] in which the authors set forth a theoretical and experimental examination of the subject matter of "Willcox's Agrobiology." The same issue contains another series of four papers[4] representing Willcox's reply. In reviewing his reply, we may first pass through our papers, taking the headings that point up the criticisms, and giving what we consider to be Willcox's reply:

1. *Early contradiction.*—Willcox states that the early contradiction should be attributed to the lack of "perspective that comes only with wide observation."

2. *Willcox's "derivation" of the nitrogen constant 318.*—No satisfactory reply. Willcox merely gives his original words in a different permutation.

3. *The Mitscherlich equation.*—a. *Validity.* Nothing new is added by Willcox, except that he quotes the "rule of halved increments." This "rule" is mathematically equivalent to the Mitscherlich equation. b. *Constancy of c.* Willcox replies that Van der Paauw's least-squares method of fitting the parameters in the Mitscherlich equation for certain data on barley and rye results in an unrealistic representation of the facts (see below). c. *Value of c.* Willcox restates his original position that 0.122 is the correct value. He says that the value 0.2, recently adopted by Mitscherlich and Atanasiu as more suitable than 0.122, applies to cases in which there is some yield depression.

4. *Yield response and nutrient absorption.*—Willcox's statements do not have logical continuity, and hence do not constitute a satisfactory reply.

5. *Recovery of added nitrogen.*—No reply.

6. *Obscurities in method of application.*—a. *The question of the proper plant part.* No reply. b. *The question of the proper nitrogen percentage.* No reply.

7. *Experimental data contradicting Willcox's conclusions.*—a. *Observed nitrogen content of plants in pot experiments.* No reply. b. *Extrapolated nitrogen content of plants in field experiments.* No reply. c. *Observed nitrogen content of plants in field experiments.* No reply. d. *Nutrients other than nitrogen.* No reply.

8. *Experimental tests on the inverse yield-nitrogen law.*—Willcox introduces his own special statistical methods, from which he reaches a conclusion opposite to that of the authors (see below).

9. *Observations on nutrient content of plants, and consequent hypotheses regarding causal relationships.* a. *Nitrogen.* No reply. b. *Other nutrients.* No reply.

The foregoing tabulation shows that Willcox has not replied to most of the criticisms made by the authors. Of the criticisms he has acknowledged, his reply is considered by the authors to be satisfactory only in the case of the first.

Following are some brief comments on Willcox's reply.

1. To justify eliminating from consideration one crop that does not agree with his ideas, Willcox supposes that the crop "is an incompletely reverted hybrid." He states that he has coined this term for the purpose of "characterizing certain anomalous hybrid sugar cane clones that show evidence of genetic readjustment." By neglecting to state precisely what these terms signify, he has provided another unverifiable hypothesis.

2. Willcox does not appear to understand mathematical manipulation, as evidenced by the last paragraph in column 1, page 321. His statement is equivalent to the following: if y is equal to the function $f(x)$, one can, by merely solving the function for x and expressing x as the function $g(y)$, impute an entirely new significance to x.

3. To obtain equation 3, page 321, Willcox states that he differentiates with respect to x_p. Equation 3, however, indicates differentiation with respect to y. The derivative he gives is not the correct one. Proceeding from this incorrect beginning, he states: "From here, by following recognized mathematical procedures, we derive a value of $x_p = 3.56$, which on conversion from metric to U. S. units turns out to be 318 pounds of nitrogen usefully absorbed from one acre of soil in one cycle of plant growth." The "recognized mathematical procedures" do not exist, in the opinion of the authors. Although he elaborates on the principles of mass action and "allometry" as justification for his mathematical procedures, he neither gives the procedures nor explains precisely how the foregoing principles apply thereto. The lack of this kind of information is exactly what the authors' original criticisms were about. The authors are perhaps as familiar as Willcox with the fact that within similar conditions of soil, crop, and environment, both yield of dry matter and yield of nitrogen are functions of the nitrogen supply in the soil, and hence of each other. Willcox has in reality said no more than this in the way of justification.

4. In justifying his use of the Mitscherlich equation, Willcox states that "any mathematical expression for the law of diminishing increments of yield in agriculture must be an expression of the rule of halved increments." (The latter is mathematically the same as the Mitscherlich equation.) Willcox's statement is false. His further peregrinations on the universality of the fraction ½ in natural processes (column 2, page 325) are beside the point.

[1] Journal Paper No. J-2599 of the Iowa Agr. Exp. Sta., Ames, Iowa. Project No. 1183. Received for publication Jan. 1, 1955.

[2] Professor of Soils, Professor of Statistics, and Graduate Assistant, respectively.

[3] Black, C. O., and Kempthorne, O. Willcox's Agrobiology: I and II, Agron. Jour. 46:303–310, 1954; and White, W. C. and Black, C. A., Willcox's Agrobiology: III. Agron. Jour. 46:310–315, 1954.

[4] Willcox, O. W. Quantitative Agrobiology: I, II, III, IV. Agron. Jour. 46:315–328, 1954.

5. Willcox concludes that the result of Van der Paauw's least-squares procedure for fitting the parameters in the Mitscherlich equation for certain data on barley and rye "belies the visible lay of the undisputed yield figures, . . . and thus gives a false picture of the observed relative yielding abilities of these two crops." Willcox's conclusion is false. He reached this conclusion by route of errors in applying Van der Paauw's results and by alterations he has made in the numerical values of published yield data. (Compare the yields of rye in his figures 2 and 3, page 328; those in figure 3 are incorrect.)

6. Willcox has given two versions of the inverse yield-nitrogen law: *(a)* "When two or more different kinds of plants are comparably grown in the same soil, that one containing the smallest percentage of nitrogen will give the greatest yield of dry substance per unit area of land surface." *(b)* ". . . The yields of all agrotypes, without any clearly proved exceptions to date, are inversely proportional to the percentage of nitrogen contained in their whole dry, above-ground substance." The former version is quoted from Willcox's reply. The latter was quoted by the authors from one of Willcox's previous papers.

The two versions are not equivalent. The first is qualitative, and the second is quantitative. The authors criticized the quantitative version. This version can be written in symbols as

$$y = \frac{k}{n}$$

where y is the yield of above-ground dry matter, n is the nitrogen percentage in the dry matter, and k is a constant, which represents the yield of nitrogen in the above-ground dry matter. The data presented by the authors showed that k was not constant under conditions where Willcox says it is constant.

Willcox does not acknowledge existence of the quantitative version. He uses this version, however, when he discusses the constancy of yield of nitrogen (or k in the above equation), and when he uses the equation $Q = 318/n$ for calculating the maximum possible yield of plants. Page 316, column 1, paragraph 4, gives an example of his use of a statement of the qualitative version of the "law" followed immediately by an application of the quantitative version. As further evidence that in practice Willcox recognizes the inverse yield-nitrogen law to have a quantitative aspect, attention may be directed to his section entitled "A Model Experiment" on pages 318 and 319.

When pressed on the quantitative version, Willcox first replies at length with the qualitative version. He then goes on, however, to use an erroneous statistical test (page 318) as a means of supplying proof that the inconstancy of yield of nitrogen found by the authors is illusory. He concludes from this that "Black and Kempthorne's arguments against this constant 318 in Parts I and II of their discussion collapse with the failure of their experimental assault on the inverse yield-nitrogen law." In addition to the fact that the conclusion is based on a faulty premise, the conclusion itself implies lack of recognition that the onus is upon him to refute the entire array of evidence the authors have brought to bear against the nitrogen constant 318.

7. Willcox's use of the word "probability" on pages 318 and 319 is incorrect. The term "probability of constancy" is a new one in the theory of probability. The method of calculation indicates that it is not a probability.

8. Willcox's statistical interpretations in the second column of page 324 and the first column of page 328 are erroneous.

9. One may question in what manner Willcox's "revitalized strip test" (which consists of a single fertilized plot bordered on each side by an unfertilized plot) referred to in column 2, page 326, obviates the need for extensive replication which he points out in the preceding sentence.

10. The authors have not been able to find in their papers two direct quotations that Willcox attributes to those papers.

11. Five statements in Willcox's papers that are purported to be verbatim quotations from the authors' papers are not verbatim quotations, but have been altered by Willcox.

12. One of Willcox's quotations involving the authors' mathematical equations contains errors that make the result nonsensical. The authors' "error", which Willcox points out in his footnote 3, page 321, is in his own misquotation, and not in our writings.

13. Comparison of Willcox's table 1, page 324, with Mitscherlich's original paper from which the data were quoted shows 10 instances in which Willcox's numerical values differ from those of Mitscherlich.

14. Willcox's table 3, page 325, contains one error in addition, one error in copying from table 1 (which may be typographical), and one error that is apparently typographical.

15. The calculated yields from Willcox's table 3, page 325, are incorrectly plotted in his figure 1 on the same page.

16. The equation given by Willcox in column 1 of page 327 to represent the response curve in figure 1 on the same page is not the equation for the curve in the figure.

In conclusion, the following statements seem appropriate: *(1)* The authors' papers supply evidence that Willcox's agrobiology is without substantial scientific basis, is internally inconsistent, and is externally in disagreement with experimental evidence. *(2)* Willcox has not refuted the arguments advanced by the authors. *(3)* Willcox's lack of recognition of old errors pointed out by the authors, together with his new errors, inaccuracy of quotation of published statements, and actual alteration of published numerical data require no comment.

In the opinion of the authors, Willcox's agrobiology is worthy of no further consideration of a scientific nature. The authors now rest their case.

SUMMARY

A review of Willcox's reply to the authors' criticism of "Willcox's Agrobiology" shows that Willcox has not refuted the arguments advanced by the authors. His reply contains numerous new errors and inaccurate quotations of the authors' writings. Numerical values of certain published data have been altered from the original. In the opinion of the authors, Willcox's agrobiology merits no further serious consideration.

Quantitative Agrobiology: V. Further Comments on Black, Kempthorne and White's Criticism of "Willcox's Agrobiology"[1]

O. W. Willcox[2]

IN THE July 1954 issue of the *Agronomy Journal* a discussion on Agrobiology comprised three papers by Black, Kempthorne and White in derogation of what they characterize as "Willcox's Agrobiology", (1, 2, 7) and four papers by me on "Quantitative Agrobiology" (12, 13, 14, 15) implying that Black, Kempthorne, and White have substantially failed to shake either of the two foundations (the inverse yield-nitrogen law and the Mitscherlich law of yield) of this most recent addition to the family of plant sciences. Black, Kempthorne and White's rejoinder appears on page 497 of this issue. This paper is my surrebuttal on their rejoinder.

A Question of Good Faith

In their rejoinder Black, Kempthorne, and White take occasion to charge me *(1)*, with bad faith in misquotation of their text and attributing to them statements which they never wrote; and *(2)*, with alteration of published numerical data. As these allegations involve a question of personal integrity, they will be attended to first.

In their paragraph numbered 12 they say: "The 'error' which Willcox points out in his footnote 3, page 321, is his own misquotation and not in our writings."

In the footnote referred to, they are quoted as follows: "Thus, if x is increased indefinitely, y approaches 318," which they rightly insist would make the result nonsensical. In the same footnote I said: "Black and Kempthorne are here confusing x_p and y. What they might have said is: if x_s is increased indefinitely, x_p approaches 318." This is, indeed, what they actually said in their printed paper ((1) I, page 306, column 1). In my reply, I took the disputed quotation, *verbatim*, from a carbon copy of their original typescript. Evidently, the statement in question was corrected before the paper was printed, and the authors neglected to notify me of its elimination.

Van der Paauw

The allegation of alteration of published numerical data is made in connection with Van der Paauw's proposal to transfer the attribute of constancy from the growth factor to the plant. According to Van der Paauw, Mitscherlich's general constant 0.6 for P_2O_5 should be changed to 0.4 for rye, while he allows it to remain at 0.6 for barley. This change in the rye factor has mathematical consequences which neither Black, Kempthorne, and White nor Van der Paauw have recognized. To appreciate the situation thus created, it is necessary to consider briefly some agrobiologic fundamentals.

In the Mitscherlich system of soil-plant relations, wherein each factor of plant growth is assigned a specific effect factor "c", the actions of a plant nutrient on two different kinds of plants may be compared by plotting the experimental yields against increasing increments of the nutrient, as in figure 2. The resulting two curves, having the same Mitscherlich factor (c = 0.6), are homologous (i.e., their y/x ratios are constant at 1.09), the slopes of the curves are analogous, and they show no tendency to cross. This figure 2 was plotted from the actual experimental data as recorded in Mitscherlich's summary of the German soil fertility survey (4). But the case is quite different when two or more fertilizers with different effect factors act on the same kind of plant. The resulting curves are then non-homologous, their inter-plant y/x ratios are inconstant, the slopes of the curves are non-analogous and the curves may show a tendency to cross. Examples of non-homologous curves are shown in figure 1, copied from Mitscherlich. This figure 1 compares the actions of P_2O_5 (c = 0.6); K_2O (c = 0.4); and N (c = 0.122)—all measured in Doppelzentner/hectare—when the same kind of plant is separately treated with increasing increments of these nutrients. The resulting curves in figure 1 obviously have inconstant y/x ratios and their slopes are obviously non-analogous. These relations warrant the statement that:

> "If two or more Mitscherlich curves are homologous (with constant y/x ratio) they have the same constant

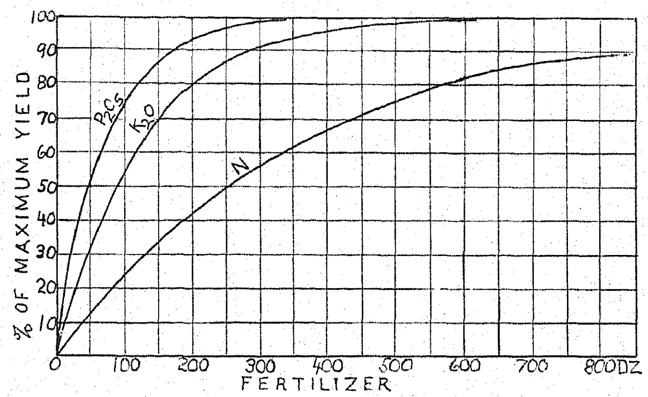

FIG. 1.—Yield increases by different fertilizers produce non-homologous yield curves.

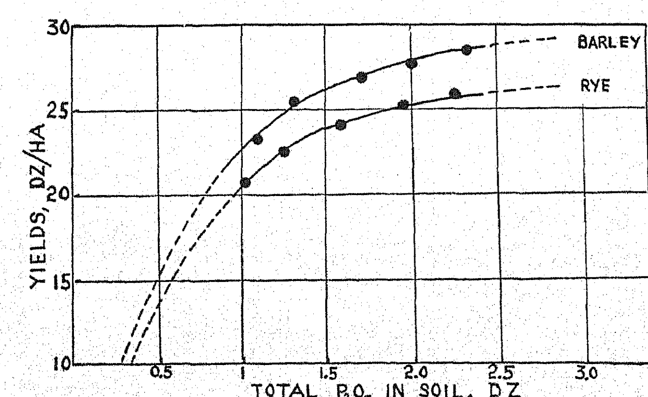

FIG. 2.—Yield curves of barley and rye, calculated with the constant 0.6 for P_2O_5. These curves are homologous; yields at corresponding ordinates show a constant ratio.

[1] Received for publication March 21, 1955.

[2] Consulting Agrobiologist, 197 Union St., Ridgewood, N. J.

c; conversely, if two or more curves are non-homologous (inconstant y/x ratio) they have different constants c."

The two curves in figure 2 clearly are homologous, while the two curves in the disputed figure 3[a] calculated from the same experimental data are not homologous. Moreover, as Black, Kempthorne, and White point out, the yield-values for rye in figure 2 are different from the values given in figure 3 (which is the fact), and they assert that the yield figures for rye in figure 3 are incorrect (which remains to be seen). On this obvious discrepancy they base the allegation that I have altered published numerical data.

This apparently anomalous situation can be clarified by making use of one of the subsidiary techniques of agrobiologic calculations: if a given plant nutrient is allowed to act separately on two different kinds of plants and the resulting yield curves are plotted on the same diagram with the x-axis scaled in appropriate units of the nutrient, the curves will be either homologous or non-homologous, depending on whether the effect factor resides in the nutrient as demonstrated by Mitscherlich and his co-workers, or in the plant if different plants have different factors as claimed by Van der Paauw. For this case the agrobiologic procedure is to scale the x-axis, not in ordinary units of weight, but in equivalent *baules* of the nutrient employed. As has been explained many times, the baule of a plant nutrient is that amount of it which is sufficient to account for half (50%) of the maximum yield obtainable when the nutrient is supplied up to the limit of the plant's capacity to give an increase of yield. The values of the baules of plant nutrients are calculated by the formula log 2/c derived from the Mitscherlich equation. Taking $c = 0.6$ for P_2O_5-on-barley and $c = 0.4$ for P_2O_5-on-rye, the corresponding baules are 50 and 75.2 (hectare basis) respectively. That is to say, a baule of P_2O_5 would be 1½ times more potent as a plant nutrient in the one case than in the other. Use of the baule as the unit of measurement puts all growth factors on the same mathematical footing, because their individual c's are compensatingly merged into the one baule coefficient 0.301; double-scaling of the x-axis is thus dispensed with, while allowing free expression of differences in nutritional potency, wherever c may reside.

It will thus be seen that in my reply (12) I, p. 328, two tests were used to show the wrongness of Van der Paauw's constant: *(A)*.—In figure 2 the curves of barley and rye are plotted, both with the same constant 0.6. The two curves turned out to be strictly homologous. Since Van der Paauw admits that the constant 0.6 is valid for P_2O_5-on-barley, the homology of the two curves automatically proves that the constant 0.6 for P_2O_5-on-rye is the right one. *(B)*.—In figure 3 P_2O_5-on-barley is plotted with the constant 0.6 and P_2O_5-on-rye with the constant 0.4, compensating the difference in nutrition value implied by the difference in constants by scaling the x-axis in baules. Since the two curves in figure 3 are obviously non-homologous, and since it is granted that the constant for P_2O_5-on-barley is 0.6, it is automatically proved that the constant 0.4 for P_2O_5-on-rye is wrong. (Here it must be stated that by an error in drafting, the legend of the x-axis in figure 3 was made to read "Total P_2O_5 in Soil, DZ."; it should have read, "Total P_2O_5 in soil, baules."

[a] See Willcox, Agron. Jour. July 1954, p. 328.

It remains to explain how the yield-values for rye in figure 3 came to be different from those in figure 2 when it is known that a constant 0.6 is characteristic of barley, and a constant 0.4 is assumed for rye. These constants may be used to calculate Mitscherlich–Baule curves for these two crops, using given sets of experimental yields for each. In such case the yield-ordinates of the curves will be determined, not by the corresponding units of nutrient measured in DZ, but by these units measured in baules, and these bauleic units will not be in the same proportion numerically because of the difference in constants. The positions of the dots on the curves representing the experimental yields will then lie higher or lower on the M–B curves than on the corresponding DZ curves. The allegedly incorrect figures for rye in figure 3 are therefore not of my invention but are values imposed by the choice of an incorrect constant for rye. Since in the present case the result is non-homology, the Van der Paauw constant must be rejected, even though it was fathered with the help of the supposedly omnipotent method of least squares (and for which, in matters affecting the direct interactions of plants and their growth factors, quantitative agrobiologists have small regard. See below).

Attempt to Invalidate the Inverse Yield-Nitrogen Law

Black, Kempthorne, and White tabulate 14 specific criticisms to which no reply has been made. A global reason for ignoring the neglected criticisms will be given farther on, and attention will first be centered on those particulars whereon their rejoinder is deemed to have failed to meet my riposte to their original criticism of "Willcox's Agrobiology".

If White and Black's experiment to invalidate the inverse yield-nitrogen law had succeeded in the expected sense, "Willcox's Agrobiology" would have been damaged beyond redemption. But it did not succeed. And the curious fact is that White and Black were apparently not aware of its failure when they published their results. They had before them the question:

> Do plants that give high yields of dry vegetable substance contain larger or smaller percentages of nitrogen than other plants giving low yields of dry substance, when the high and the low yielding plants are grown on equal areas of the same uniform soil?

This question can be answered by a competently executed experiment. Such an experiment consists in planting two or more different kinds of plants on equal areas of the same uniform soil that have been supplied with increasing doses of nitrogen fertilizer, weighing the yields of dry substance from each nitrogen treatment, and determining the average percentage of nitrogen contained in the dry substance harvested from that treatment. This done, the next step is to arrange the various yields of dry substance in the order of their increasing magnitudes, and to place opposite each yield figure its corresponding percentage of nitrogen. With the data so tabulated, the figures in the nitrogen column will be either in the inverse order of the figures in the yield column, or they will show no regular order, and consequently no consistent relation between yield of dry substance and nitrogen percentage.

White and Black omitted the last step. They tabulated their data indiscriminately, with no regard to numerical order of either yields or nitrogen percentages. In this scrambled arrangement of the figures, no support for the inverse yield-nitrogen law could readily be seen, so White and Black were ready with "proof" of the invalidity of the law. In examining such an experiment, the first care should be to arrange the yields in their orders of magnitude opposite the corresponding nitrogen percentages. Thereupon, the nitrogen percentages showed up in inverse order to the yields. And so here, as in countless other cases, the inverse yield-nitrogen law asserted itself.

White and Black's omission to take this last step (the only procedure that could reveal the situation for which they were ostensibly seeking) might be regarded as an inadvertance. But their omission to make a frank acknowledgment of the error is another matter. Instead, in a long passage on the qualitative and quantita-

tive aspects of the inverse yield nitrogen law, they now insist that they were criticising only the quantitative aspect (i.e., that all kinds of plants grown under comparable conditions contain substantially the same quantity of nitrogen, by weight, regardless of the quantity of non-nitrogenous substance they severally produce). This is an oblique admission that in its qualitative aspect (i.e., nitrogen percentage is inverse to total yield of dry substance) the law is valid. To prove the non-existence of the quantitative relation they applied an analysis of variance to the differences of nitrogen yields in connection with yield of dry matter; this statistical operation is said to have shown that different kinds of plants do not necessarily contain the same *quantities* of nitrogen.

In examining this portion of their data I found that the situation could be adequately handled by calculating the average deviation of the means of the nitrogen contents; this showed probable constancy within a range of 92.2 to 96.5%—a degree of probability which, considering the quality of their experimental work in comparison with a cited experiment (Pazler) of unquestionable accuracy, may still be deemed reasonably confirmatory of the quantitative aspect of the law.

The Nitrogen Constant 318

Paragraph 2 of the second section of Black, Kempthorne, and White's review of my reply opens with the statement that "Willcox does not appear to understand mathematical manipulations." They find occasion for this supposition in a typographical error in my reply. This occurred in a phrase near the bottom of col. 1, p. 321 (13) "differentiated with respect to x_p"; a competent mathematician could see that this should have read "differentiated with respect to y." Taking this accident as a cue, they allege that what I intended to say was: "if y is equal to the function of (x) one can, by merely solving the function of x and expressing x as the function of g(y) *(sic)*, impute an entirely new significance to x"; this is nonsensical.

However that may be, what they are now saying is a complete reversal of what they said in their original paper. Refer to the passage in their Part I, col. 1, p. 306 (1) where they discuss my derivation of the constant 318, and give their understanding of how I arrived (9) at the equation:

$$X_p = 318\ (1 - 10^{-cx})$$

From there they go on to say:

> "The procedure up to this point is straightforward. Equation 9 is mathematically correct. If we now interpret X_p to be the nitrogen in the plant and X the amount of N present in the soil, we obtain an equation that is in accord with Willcox's ideas. Thus, as X is indefinitely increased, X_p approaches 318."

What is this but an admission that my procedure has been straightforward, and that my derivation of the nitrogen constant is mathematically legitimate? But they go on to say:

> "There is nothing in the mathematics, however, to justify the interpretation that X_p *is the nitrogen in the plant.* The manipulations therefore do not constitute a derivation of the nitrogen constant 318. . . . Since Willcox has, in effect, snatched a figure from the air, he cannot be proved wrong on a theoretical basis unless theory demands some other value."

And there is the crux. They approve my mathematics (except when they take advantage of a harmless typographical error to create an appearance of confusion). But they cannot understand what could give origin to the concept x_p. In their review of my reply they complain that

> "although he (Willcox) elaborates on the principles of mass action and 'allometry' as justification for his mathematical procedures, he neither gives the procedures nor explains how the foregoing principles apply thereto. The lack of this information is exactly what our original criticisms were about."

It seems to this writer that a person who has formed the habit of close reading of technical papers should easily find in my reply a description of the procedures and principles involved, and also a clear exposition of the concept x_p; see (13) my Part II, col. 2 at the bottom of p. 320, beginning with the section headed "Distribution of nitrogen between soil and plant."

Though skilled in the use of pure mathematics, they appear to be unskilled in the meaning and mathematical applications of the general mass action law to the mineral nutrition of plants. In their review of my reply they confidently assert that:

> "The authors are perhaps as familiar as Willcox with the fact that within similar conditions of soil, crop, and environment, both yield of dry matter and yield of nitrogen are functions of the nitrogen supply in the soil, and hence of each other."

As to that, I am inclined to allow the informed reader to apply the adage: "by their works ye shall know them."[8]

Their assertion that my statement: "any mathematical expression for the law of diminishing increments of yield in agriculture must be an expression of the rule of halved increments" (the latter is mathematically the same as the Mitscherlich equation) is false," may be left to the judgment of readers who have made themselves familiar with the vast mass of factual evidence in support of the Mitscherlich law of yield that has accumulated during the past 46 years.

The Real Question at Issue

Black, Kempthorne, and White complain that I have taken no notice of the theory which they offer as a substitute for the inverse yield-nitrogen law. It is my opinion that no plant nutritionist who has a working acquaintance with the distribution of nitrogen between plant and soil as a mass action function would give their theory a second look.

They further complain that no reply, or no satisfactory reply, has been made to most of their criticisms, and they insist that ". . . the onus is upon him (Willcox) to refute the entire array of evidence the authors have brought to bear against the nitrogen constant 318."

Their citations of experimental work reported by Rackmann; Borden; Bishop; Carpenter, Haas and Miles; Robinson; Dreyspring, Kurth and Heinrich were ignored because the conclusions which Black, Kempthorne, and White draw therefrom are no better than inconsequential "quibbles" that do not warrant the space that would be required for discussing them and which could be better used for considering the decisive matter around which the whole controversy revolves. That decisive matter is whether the Mitscherlich yield equation is the sole authentic mathematical expression for the formidable law of diminishing increments of yield in agriculture that holds undisputed rule over all quantitative relations between the yields of plants and the factors of their growth. The disputed constant 318 derives from the Mitscherlich equation; to upset this constant, it is necessary to upset the Mitscherlich equation. Therefore Black, Kempthorne, and White should accept "the onus of refuting the whole array of evidence" that

[8] It may again be suggested that soil scientists and plant physiologists would do well to familiarize themselves with Mitscherlich's "Über allgemeine Naturgesetze." Schriften der Königsberger gelehrten Gesellschaft I, Naturwissenschaftliche Klasse, Heft 3 (1924).

supports the Mitscherlich equation. Within the limited space assigned to this discussion, it is not feasible to launch a review of the vast record of experimental data on which quantitative agrobiologists base their unreserved acceptance of the Mitscherlich equation; but at least one robust example should be cited.

The selected example is the German soil fertility survey of the 1930's wherein, over a wide range of soil conditions, cultural practices, climatic influence, and different kinds of crop plants, the authenticity of the Mitscherlich yield equation and the constancy of the Mitscherlich effect factors for the principal plant nutrients were demonstrated by the average results of 27,069 Grade A field tests, distributed over a great expanse of varied territory. Summaries of this enormous work are given in (3, 4, 16). A condensed tabulation of the numerical data and an estimate of the probable accuracy of the average results are given in (11). The upshot of this investigation, which still stands as the most extensive collaborative enterprise in all the history of agricultural experimentation, was to confirm the values of Mitscherlich's constants within a probability of approximately 99:1.

To be sure, the worth of this great soil survey as experimental evidence for the Mitscherlich equation and its factors has been impugned by Stollenwerk (5) and by Van der Paauw (6). It has not been difficult to show (11) how these efforts aborted, in the one case by a fatuous mathematical approach, and in the other case by a misdirected use of the method of least squares, which contemporary writers of statistical texts for agricultural workers have mistakenly come to regard as a master solvent in problems affecting fertilizer tests. This brings up another subject.

The Statistical Problem

In their review of my reply Black, Kempthorne, and White allude to my use of what they regard as erroneous statistical tests and to "Willcox's own special statistics" and thus to arrive at conclusions different from theirs.

What they apparently have not realized is that, when an agriculturist has qualified as a quantitative agrobiologist by making an intimate acquaintance with the Mitscherlich theorem and its related concepts, he sees a remarkable change (or one might say, a tremendous simplification and increase of accuracy and precision) coming over statistical procedures applicable to the evaluation of fertilizer tests. This change in statistical base involves a shift from the *abstract* Gaussian theory of probability that is extensively elaborated in the works of Fisher, Yates, Snedecor, Cox, Cochrane, and others, to the very *concrete* realities of plant growth and crop nutrition, which are now known to depend on specific natural laws that put these realities remote from the domain of chance. This change was foreshadowed in some earlier papers (8, 14) and has been more particularly developed in two recent publications (9, 11). Given a knowledge of the practical applications of the Mitscherlich yield equation, some skill in use of the standard agrobiologic yield diagram, an understanding of the principle of the reproducibility of natural phenomena, and the associated concept of "absolute values" in plant culture, an operator who has to do with the testing of fertilizers by the pot or the field method needs only to know how to apply the simple formula $Sd/n\sqrt{n-1}$ and to do some figuring in percentage. Of such are the procedures used in my critique of Black, Kempthorne, and White's work.

As concerns the quantitative agrobiologist when he is mainly interested in the direct response of crops to fertilizers, the highly abstract trappings of contemporary experimental statistics—method of least squares, regressions, analysis of variance, t tests, F values, and even the cherished principle of randomization—have lost the values imputed to them and to which, in fact, they never have been entitled. This does not mean that quantitative agrobiologists make no use of conventional statistical methods in any experimental conjuncture, but only that in the restricted field of crop nutrition these methods are discarded because they lack the specificity and trustworthiness afforded by the Mitscherlich law of yield, the inverse yield-nitrogen law, and the mass action law.

RESUME

From the foregoing it may be concluded that Black, Kempthorne, and White's assault on quantitative agrobiology has in general miscarried because of their failure to discredit the Mitscherlich yield equation and the constancy of its effect factors. In particular, their attack on the inverse yield-nitrogen law and the nitrogen constant 318 aborted because of the inadequate precision of their experimental work; their critique of the constant 318 is without point because of inadequate consideration of the part played by mass action in plant nutrition. Moreover, for reasons stated, current methods of statistical analysis have not, and never have had, any valid application to the direct interaction of crops and fertilizers.

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Studies of Inheritance in *Lespedeza cuneata* Don[1]

R. P. Bates and P. R. Henson[2]

SERICEA lespedeza, *Lespedeza cuneata* Don., is a deep-rooted perennial legume well adapted to the soils and climate of the Southeastern States. Sericea, however, is not as widely used as it might be, due very largely to its low palatability. Improvement programs with sericea would be strengthened by knowledge of the inheritance of the tannin complex, the relationship of tannin to other characters, and the inheritance of plant height, maturity, seed size, and seed, plant, and flower color.

REVIEW OF LITERATURE

In 1939 Clarke, *et al.* (2) stated: "It is evident that sometimes something is present in *Lespedeza sericea* in sufficient quantity to lower its palatability and interfere with digestion. One constituent that might be responsible for these objectionable features is tannin, since it is distasteful and astringent". In 1953 Wilkins, *et al.* (8) obtained preliminary data which indicated that tannin content affected the amount of sericea forage consumed by sheep. Donnelly (3) found from grazing studies that tannin, in addition to stem type, affected the palatability of *L. cuneata.*

Even though tannin content of sericea lespedeza has been found to vary with several environmental factors, sufficient evidence has been obtained to indicate that there are inherent differences present. Stitt (6) concluded that enough variation was found in tannin content between sericea clones so that selection from different seed sources could be very effective in isolating clones lower in tannin. Tannin was found to be positively correlated with plant height; and in some cases, negatively correlated with leafiness of the plant. Stitt's results also indicated inherent differences in plant height, number of shoots, leafiness, dry matter, and yield. Stitt and Hyland (7) found that tannin was negatively correlated with protein content of the plant.

MATERIALS AND METHODS

Parent material.—Five sericea plants, representing extremes in several characters, were selected in 1951 from a large spaced planting of different sources of sericea lespedeza. A brief description of these plants is given in table 1.

Crossing technique.—Crosses were made without emasculation. The method used was described by Hanson (4) who worked with *L. stipulacea.* Flowers for pollen were selected each morning. The young buds selected for crossing were 4 to 6 mm. long and usually 1 to 2 days before anthesis. The corolla was split with a dissecting needle and fresh pollen from the other parent dusted on the stigma and the cross marked with small tags. The crosses, number of pollinations, number of seed and the number of F_1 plants obtained were as follows:

Crosses	Number of pollinations	Number of seed	Number of F_1 plants
A–1-10-14 × 5-38-1	282	93	35
B–1-10-20 × 5-30-7	278	58	16
C– 1A-62 × 5-30-7	75	14	5

Growing populations.—The crossed seed of crosses A and B were hulled, the seed coat of each punctured with a dissecting needle, and placed in soil in the greenhouse on Oct. 26, 1951. Because of the late maturity of 1A-62, seed of cross C were not planted until Nov. 12. At the same time, S_1 seed (from cleistogamous flowers) of each of the parent plants were also planted. The first group of seedling plants was transplanted to 3-inch pots on Nov. 21 and the second group on Dec. 4. One hundred S_1 plants of each parent were grown along with the F_1 plants. Plants were placed under an 8-hour day length on Feb. 6, 1952, in an effort to initiate seed production. A month later, seed pods in cleistogamous flowers were visible. Relatively few seed were produced, resulting in rather small F_2 populations. All F_2 and S_2 seed were harvested by June 1, at which time the plants were cut back and transplanted to the field for further study.

F_2 and S_2 seed from each parent were germinated June 1 and planted in individual 2-inch pots in the greenhouse. On June 25 they were transplanted to the field in 40-inch rows, spaced 2 feet apart and in the row in 5 equal replications. The number of plants in each S_2 and F_2 population was as follows: (1–10–14)—250, (1–10–20)—200, (5–38–1)—150, (5–30–7)—250, (1A-62)—250, (1–10–14 x 5–38–1)—167, (1–10–20 x 5–30–7)—110 and (1A-62 x 5–30–7)—65.

Evaluating characters.—Tannin content was estimated for the individual plants through the use of paper treated with a 2.5% solution of ferric ammonium citrate. By this method, 1 or 2 sericea leaves were placed between a folded strip of the treated paper and squeezed with a pair of smooth-jawed pliers. Plant juice from the leaves made a gray to black spot on the paper, the darker colored spots indicating low to high tannin content. Highly significant correlations between this method and the hydrochloric acid-formaldehyde and official hide power methods of tannin analysis were obtained.[3]

Plant height was recorded twice in the F_1 and S_1 populations, once in the greenhouse and once in the field. The F_2 and S_2 populations were measured in the field one time only.

Flower, seed, and plant colors were evaluated by ratings from 1 to 5, with 1 being cream flowers, green seed and green plants, and 5 being purple flowers, seed and plants. Intermediate numbers refer to intermediate colors in each case.

[1] Contribution from Field Crops Res. Br., A.R.S., U.S.D.A. Part of a thesis submitted to the University of Maryland, College Park, Md., by the senior author in partial fulfillment of the requirements of the Ph.D. degree. Received May 31, 1955.

[2] Associate Plant Breeder, Samuel Roberts Noble Foundation, Ardmore, Okla., and Research Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A., respectively.

[3] Bates, R. P. Studies of inheritance, photoperiodic response, and determination of tannin content of *Lespedeza cuneata* Don. Ph.D. thesis, University of Maryland, 1953.

Table 1.—Description of five sericea plants used in this study.

Plant number	Tannin content	Plant height inches	Flower color	Seed color	Plant color	Seed maturity	Seed weight g./1000	% chasmogamous seed
1-10-14	low	24	cream	green	green	late	1.18	7.7
5-38-1	high	14	cream	purple	green	early	1.67	6.1
1-10-20	low	27	cream	green	green	medium	1.38	2.6
5-30-7	high	15	purple	green	purple	late	1.57	25.6
1A-62	high	15	cream	purple	green	early	1.68	0.8

Maturity ratings were given each plant on Oct. 15, with 1 being all immature seed and 5 being all mature seed. Plants having immature and mature seed were given intermediate rating.

Seed size was determined by weighing 300 seed from cleistogamous flowers from each plant. Weights were recorded in grams per 1,000 seeds.

Percent seed produced from chasmogamous flowers was determined by counting the number of chasmogamous seed in a sample of 500 seed from each plant.

Analysing data.—Heritability was calculated with the formula presented by Mahmud and Kramer (5). The formula is as follows:

$$H = \frac{\sigma F_2 - \sqrt{\sigma^2 P_1 \cdot \sigma^2 P_2} \times 100}{\sigma^2 F_2}$$

where: $\sigma^2 P_1$ = variance of parent 1
$\sigma^2 P_2$ = variance of parent 2
$\sigma^2 F_2$ = variance of F_2 plants.

Gene number for each character in each cross was estimated with one of Wright's formulas which was used by Burton (1) in quantitative inheritance studies with pearl millet. The formula is as follows:

$$N = \frac{0.25\,(0.75 - h + h^2)\,D^2}{\sigma^2 F_2 - \sigma^2 F_1}$$

where: $h = \frac{\overline{F}_1 - \overline{P}_1}{\overline{P}_2 - \overline{P}_1}$

$D = \overline{P}_2 - \overline{P}_1$
$\overline{P}_1$ = mean of small parent
$\overline{P}_2$ = mean of large parent
$\overline{F}_1$ = mean of F_1 plants
$\overline{F}_2$ = mean of F_2 plants

In addition to the above calculations, frequency distributions for each character were determined in the respective F_2 populations. Bar graphs were constructed showing percent of plants in each class or rating of characters studied in the various crosses. Correlation coefficients were calculated between pairs of characters studied in each cross.

RESULTS AND DISCUSSION

Tannin content.—More variation was found in F_2 populations for tannin content than in the S_1, S_2, F_1 populations. Tannin content of majority of plants in F_1 and F_2 populations ranged between that in S_1 and S_2 populations of respective parents. Of 167 F_2 plants from cross A, 7, 51, 94, and 15 were scored 5, 6, 7, and 8 respectively; while in cross B with 110 plants in the F_2, 6, 29, 60, and 15 were scored 5, 6, 7, and 8, respectively. Parental S_2 means were 5.5 and 8 for cross A, and 6 and 8 for cross B.

Evaluations for tannin content were made just before the plants began flowering. The same type of tannin rating was made on 700 sericea plants in seedling stage (6 to 8 inches tall), pre-flowering stage, and flowering stage. Simple correlation coefficients between pairs of these stage were all significant at the 0.05 level, indicating that relative tannin content of different plants is about the same at different stages of growth. Tannin content of a given plant was found to increase to about mid-season and then decrease again. Observations indicate that tannin content of some plants increases more during the season than that of others. In most cases tannin content was lower in plants that were stunted and growing very slowly. This was especially true in seedling plants. In general, young leaves were a little higher in tannin than were older leaves of the same plant. Terminal buds appeared to contain more tannin than any other part of the plant.

Estimated heritability of tannin content as determined from the F_2 population was 43 and 34% for crosses A and B, respectively. A comparison of heritabilities and gene numbers for tannin content with those of other characters is given in tables 2 and 3, respectively. Gene number involved in tannin inheritance was 24 and 19 for crosses A and B, respectively. Tannin content of plants in F_2 populations was positively correlated with seed color following cross A, but was not significantly correlated with any of other characters. Table 4 gives correlation coefficients between pairs of the various characters studies in *L. cuneata*. This work leaves no doubt that plants can be selected which are lower in tannin content than average tannin content of commercial seed stocks. It was also indicated that this character can be transferred by hybridization, and that plants of varying tannin content can be selected from segregating populations following the cross. It was apparent that inheritance of tannin content is complex and that genetic factors, in some cases, do not account for as much variation as environmental factors. Genetic factors controlling tannin content do not appear to be strongly linked with those controlling other characters studied. A few plants were recovered in F_2 populations that appeared to have a tannin content below that of the lower parent. This indicated that hybridization of two plants relatively low in tannin might yield new genetic combinations in segregating generations that are still lower in tannin content.

Table 2.—Heritability estimated for characters in *Lespedeza cuneata.*

Characters	Crosses		
	A	B	C
Plant height	53.8	59.8	—
Tannin content	43.0	34.0	—
Maturity	91.2	—	89.8
Flower color	—	93.0	91.7
Plant color	—	91.3	89.9
Seed size	91.2	—	75.3
%chasmogamous seed	—	35.1	36.6

Table 3.—Estimated gene numbers for inheritance of characters in *Lespedeza cuneata.*

Characters	Crosses		
	A	B	C
Plant height	34	13	—
Tannin content	24	19	—
Maturity	22	—	10
Flower color	—	11	8
Plant color	—	16	12
Seed color	1	—	1
Seed size	4	—	—
% chasmogamous seed	—	102	58

Plant height.—In F_2 populations, segregates were recovered which appeared identical to each parent involved in the cross. Most progenies, however, were intermediate in growth habit and plant height. In cross A, seedling F_1 plants appeared to be identical to seedling S_1 plants from the male parent, but the same F_1 plants when mature were similar to mature S_1 plants from the female parent. In this cross, F_2 plants segregated for plant height in both the seedling and mature stages of growth.

Estimated heritability for plant height in crosses A and B was 53.8 and 59.8, respectively. Estimated number of genes involved in inheritance of plant was 34 in cross A, and 13 in cross B. In cross C, plant height was negatively correlated with maturity and seed size; however, the difference in plant height between these two parents was small. Evidence of hybrid vigor was present in one cross but not in the other. In both F_2 populations, plants were recovered which did not resemble either parent. This study indicated that such characters as large leaves, increased leafiness, and fine stems can be combined to give a more desirable plant type. By a backcross program, plant height and plant type can probably be combined with any other characters studied. The only evidence of linkage was with maturity and seed size in cross C.

Maturity.—Heritability values of 91.2 and 89.8 were obtained for maturity in crosses A and C, respectively. Number of genes involved was estimated to be 22 in cross A, and 10 in cross C. Maturity was positively correlated with seed color and seed size in both crosses, and negatively correlated with plant height in cross C. No correlation was shown with the other characters. Neither of the segregating populations showed a normal distribution. Late transplanting to the field probably explains why F_2 distributions were skewed toward late maturity. Even though inheritance of maturity appears rather complex, it appears that maturity date can be transferred in *L. cuneata*. The only characters closely related to maturity were seed size and seed color. These relationships probably existed because many seeds on late plants were immature at the first frost.

Flower color.—The heritability value for flower color was 93.0 for cross B and 91.7 for cross C. Number of genes was estimated to be 11 for cross B, and 8 for cross C. Flower color was highly correlated with plant color in both crosses. Plants with purple flowers usually developed a purple color in their leaves and stems during periods of low temperature. A positive correlation existed between flower color and any of the other characters. Distributions for flower color in F_2 populations were much like those for maturity. Flower color does not appear to be affected by planting at flowering time, so the skewness of these distributions is probably not due to late transplanting to the field. From F_2 distributions, the greater frequency of cream flowers might appear to be due to dominance, but all F_1 plants had purple flowers, indicating that purple is dominant. Flower color was strongly associated with plant color, and independent transfer of this character without plant color would probably require large populations in generations following crosses.

Plant color.—This character refers to a purple pigment formed in leaves and stems of plants late in the season as a result of low temperature. Evidently this color is not initiated by short day length since there was no indication of such in photoperiodic studies with sericea lespedeza.

Table 4.—Correlation coefficients between several pairs of characters in F_2 populations of *Lespedeza cuneata*.†

Characters	Crosses		
	A	B	C
Tannin content and maturity	0.147	—	0.250
Tannin content and flower color	—	0.044	.112
Tannin content and plant color	—	.082	.107
Tannin content and seed size	.001	—	.138
Tannin content and seed color	.286**	—	.098
Tannin content and % chasmogamous seed	.113	.053	—
Tannin content and plant height	.037	−0.028	—
Plant height and maturity	.006	—	−0.302*
Plant height and flower color	—	−0.090	− .243
Plant height and plant color	—	.002	− .014
Plant height and seed size	.035	—	− .292*
Plant height and seed color	−0.018	—	− .118
Plant height and % chasmogamous seed	—	.077	− .113
Maturity and flower color	—	—	.031
Maturity and plant color	—	—	−0.229
Maturity and seed color	.530**	—	.485**
Maturity and seed size	.253**	—	.342*
Maturity and % chasmogamous seed	.072	—	.190
Flower color and plant color	—	.769**	.638**
Flower color and seed color	—	—	.184
Flower color and seed size	—	.041	.184
Flower color and % chasmogamous seed	—	.009	.050
Plant color and seed color	—	—	.059
Plant color and seed size	—	—	−0.212
Plant color and % chasmogamous seed	—	.091	.296*
Seed color and seed size	—	—	.226
Seed color and % chasmogamous seed	−0.042	—	−0.219
Seed size and % chasmogamous seed	−0.017	—	.152

† Degrees of freedom varied slightly from character to character, but in general they were 165, 108, and 63 for crosses A, B, and C, resp.
* Significant at the 5% level.
** Highly significant at the 1% level.

Purple color also appeared in plants carrying this character if they were transplanted to the field early in the season. Plant color was found to be controlled to the extent of 91.3% in cross B and 89.9% in cross C by heritable factors. Number of genes controlling this character were estimated to be 16 for cross B, and 12 for cross C. Plant color was positively correlated with flower color in both crosses, and with percent chasmogamous seed in cross C. It is possible that in regions where sericea lespedeza is better adapted, this character might never become evident. This color was not correlated with tannin content or growth type, and probably would never have importance in sericea lespedeza breeding, with the possible exception of being used as a varietal marker.

Seed color.—In S_1 populations of purple-seed parents, all seed was purple; but in S_2 populations of the same parents, some green seed was present. Green seed from S_2 plants appeared to be a result of immaturity, since S_2 plants produced seed late in the season and some of the seed was a little immature at first frost. When S_2 seeds from a single plant were separated into immature seed, partly mature seed, and well matured seed before being hulled, it was found that immature seed was green, partly mature seed had a purple cast, and well matured seed was solid purple. Some F_2 plants showed the same sort of segregation, while some plants had all green seed regardless of maturity. The number of F_2 plants in cross A with purple mature seed was 102 to 47 plants wth all green seed. In cross C the numbers were 38 purple and 10 green. Heritability for seed color was not calculated since the effect of maturity was so pronounced. Number of plants with some purple seed was roughly three times the number with all green seed. If the assumption is correct that plants with some purple seed carried the genotype for purple seed, then this character appears to be controlled by a single pair of genes. In addition to maturity, seed color was positively correlated with tannin content in cross A, and flower color in cross C. In some *L. cuneata,* seed are also present which have purple-speckled seed coats. In S_1, S_2, F_1, and F_2 populations, no speckled seed were found, indicating that perhaps this is controlled by another entirely different set of genetic factors. Due to lack of time and unimportance of the character, its inheritance was not studied further. The solid purple color might be desirable as a varietal marker.

Seed size.—Seed size was expressed as gram weight of 1,000 seeds from cleistogamous flowers. There was a great difference in seed size between parents of cross A, but very little difference between parents of cross C. Heritability values of 91.2 and 75.3 were obtained for crosses A and C, respectively. Estimated gene number in cross A was 4. Number of genes involved in cross C was not calculated since the difference between parents was very small. In both crosses, seed size was positively correlated with maturity, and in cross C it was negatively correlated with plant height. There was no correlation between seed size and the other characters. Seed size is considered a rather important character from the point of view that increased seed size results in increased seedling vigor. This has been indicated with sericea seedlings in the greenhouse. In general, seedling vigor of this species is very poor and establishment of new seedlings is slow. Often very little use can be made of the first year's growth due to the slow rate of establishment. This study indicated that seed size is controlled by a fairly small number of genes, and large seed size could probably be transferred to more desirable lines.

Percent of seed produced from chasmogamous flowers.—F_2 plants of crosses B and C produced relatively few seeds from chasmogamous flowers. This is probably because at the time of seed setting, day length was short and the temperature was relatively low. These are two conditions which favor seed production from cleistogamous flowers. The percent heritability was calculated to be 35.1 for cross B and 36.6 for cross C. An estimated gene number of 102 and 58 was involved in the two crosses, respectively. Percent chasmogamous seed was positively correlated with plant color in cross C, but showed no correlation with the other characters. In a breeding program seed from cleistogamous flowers provide an easy way of obtaining selfed seed, while if hybridization is necessary a rather high proportion of chasmogamous flowers is needed. During this study, day length and temperature was found to affect this character greatly. This study also indicates that the proportion of chasmogamous and cleistogamous flowers is inherited, but the inheritance is apparently very complex. The heritable portion of this character comprised only about one-third of its total variation.

SUMMARY

Three crosses were made between individual plants of *Lespedeza cuneata.* Parents were selected so that information could be obtained on the inheritance of eight characters in two different crosses. Characters studied were tannin content, plant height, maturity, flower color, plant and seed color, seed size, and percent chasmogamous seed.

Heritability and gene number estimates were made for each character in the two crosses. Correlation coefficients were calculated between pairs of characters. Approximately 40% of the variation in tannin content in F_2 populations was accounted for by heritable factors. An estimated 20 to 25 gene pairs were involved in tannin inheritance. The only evidence of linkage involving tannin content occurred in one cross where seed color and tannin content were found to be associated. About 55 to 60% of variation in plant height in F_2 generations was inherited. Plant height of mature plants was controlled by about 34 gene pairs in cross A, while cross B involved about 13 pairs. In cross C, plant height was negatively correlated with maturity and seed size. Heritability of maturity in F_2 populations was about 90%. Estimated gene number in cross A was 22, while in cross C it was only 10. There was some evidence of association between maturity and seed color and seed size. Inheritance of flower color appeared to involve about 10 pairs of genes, and about 92% of variation in F_2 populations was due to genetic factors. Flower color was strongly associated with plant color and showed some association with seed color. Heritability of plant color was estimated to be about 90%, while number of gene pairs involved in inheritance of this character appeared to be 12 to 16. Solid purple seed color seemed to be simply inherited. No plants were found in the F_2 populations with a speckled or flecked seed coat. The flecked seed coat is often found in *L. cuneata* and since none was found in segregating populations, it appears to be controlled by an independent set of genetic characters. Seed size appeared to be rather simply inherited, with about 4 pairs of genes. Heritability values ranged from 75 to 91%. The proportion of seed from chasmogamous flowers was complex in its inheritance, with estimated gene number ranging from 58 to 102. Only

about 36% of variation in this character was due to heritable factors.

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Officially Graded Hay and Its Chemical Composition[1, 2]

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HAY is graded on the basis of its odor and physical appearance. It is assumed that such characteristics are associated in varying degrees with feed value and chemical composition. It is the purpose of this paper to present new and more specific data on these relationships.

The important physical characteristics that can readily be evaluated have been listed by Pollock and Hosterman (6) as follows: *(1)* stage of maturity or ripeness when cut, *(2)* percentage of leaves, *(3)* percentage of natural green color, *(4)* percentage of foreign material, *(5)* size and pliability of stems, and *(6)* aroma.

The U. S. hay standards (8) provide for such an evaluation of hay. Data on the relationship between graded hay and its feeding value are extremely limited. Feeding trials have been conducted in order to determine the value of some officially graded hay. This procedure has been expensive, time-consuming, and often inconclusive, the results applying only to a few types of hay.

This paper reports the chemical analyses of officially graded samples of hay collected from numerous farms as part of a survey study of the quality of hay produced in New Jersey.

PROCEDURE

Hay samples were collected from 10 dairy farms in each of 8 New Jersey counties during the 4 winter feeding periods 1948–49 through 1951–52. The mows of hay were sampled 5 times during the winter, once each month from November through March. A bale "slice" or sample of at least 6 pounds was taken from the hay currently being fed to the dairy animals. Samples were assembled monthly at the New Jersey Experiment Station for official grading.

After the samples were graded, they were ground and subsampled for chemical analysis. The analyses consisted of quantitative determinations of crude protein, crude fat (ether extract), crude fiber, ash, and moisture content. The methods of analyses were those of the Association of Official Agricultural Chemists (1). The nitrogen-free extract content of each sample was computed by difference. All values other than moisture were adjusted to a 10% moisture basis.

RESULTS AND DISCUSSION

A total of 1,775 samples of hay, representing 16 official hay classes, were collected from New Jersey farms. The important hay species in the various mixtures were alfalfa, red clover, and timothy. Found in relatively small amounts were alsike clover, ladino clover, bromegrass, orchardgrass, ryegrass, bluegrass, reed canarygrass, redtop, and several weedy-type grasses. Over 60 types of weeds and other foreign material were identified.

On the basis of average legume content, 9 hay classes were predominantly legume and 7 classes predominantly grass (See table 1.)

The data in tables 1 and 2 give evidence that as the legume content of the hay decreased, the content of crude protein and ash decreased and crude fiber and NFE increased. This is in substantial agreement with other investigations (7, 10) in regard to the naturally higher protein and mineral content and lower carbohydrate content of legumes compared with grasses when cut at the hay stage.

There were exceptions to these trends in this study that are worthy of note. Classes containing relatively large amounts of red clover (Clover Hay and Clover Timothy Mixed Hay) were significantly lower in crude protein and somewhat lower in crude fiber than alfalfa and alfalfa mixed hay classes of similar legume content.

Also, the data show that Alfalfa Light Grass Mixed Hay and also Alfalfa Heavy Grass Mixed Hay were not significantly lower in crude protein than alfalfa hay. The grass component of both classes consisted to a large degree of immature bromegrass, crabgrass, or timothy. The presence of the immature grass in the mixture undoubtedly increased the crude protein content of the hay and at the same time reduced the percentage of crude fiber.

Evidence that the requirements for the class "alfalfa hay" are overly strict is suggested by these data. Additional data from feeding trials support this observation. Gordon, *et al.* (4) found that feeding dairy heifers Alfalfa Light Grass Mixed Hay gave greater gains than Alfalfa Hay of the same grade. The average chemical composition of each class is presented in table 2.

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[2] Acknowledgment for participation in these investigations is given various members of the Extension Service, Farm Crops Department and Agricultural Chemistry Department. Part of the study on which this report is based was made under the authority of the Agricultural Marketing Act (RMA Title II).

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Table 1.—Range and average legume content of samples from 16 hay classes. New Jersey hay quality survey 1948–1951.

Class	Samples	Legume content	
		Range	Average
	Number	%	%
(Predominantly legumes)			
Alfalfa Hay	446	95–100	99
Alfalfa Clover Mixed Hay	22	90–100	95
Clover Hay	76	80–100	88
Alfalfa Light Grass Mixed Hay	130	80–94	85
Alfalfa Light Timothy Mixed Hay	68	70–94	79
Clover Timothy Mixed Hay	72	51–79	65
Alfalfa Heavy Grass Mixed Hay	95	40–79	60
Mixed Hay	165	10–95	55
Alfalfa Heavy Timothy Mixed Hay	56	31–69	54
(Predominantly grass)			
Timothy Heavy Clover Mixed Hay	69	31–50	42
Timothy Light Alfalfa Mixed Hay	86	11–30	25
Timothy Light Clover Mixed Hay	69	11–30	24
Grass Hay	83	0–39	13
Timothy Hay	236	0–10	3
Timothy Light Grass Mixed Hay	33	0–10	3
Timothy Heavy Grass Mixed Hay	30	0–10	2

It would seem desirable that several hay class requirements be revised in order to modify situations such as those shown above. A large number of hay classes was encountered in this survey of New Jersey made hay. Sixteen perennial type hay classes and six classes of annual hays were identified. A revision of class limits to reduce the number of classes or types of hay described in the U. S. Standards would serve to simplify the system and encourage its wider use.

A review of the various classes reveals that alfalfa mixtures with grass and with timothy are repetitious in terms of feed value. Both light and heavy mixtures of timothy (and grass) with alfalfa are provided for, and, in addition, a timothy light alfalfa mixed hay class is described. Four grass mixtures (timothy, grass, timothy light grass, and timothy heavy grass mixed hay) are used. The class "Mixed Hay," a catchall for hays not otherwise defined in the standards, varied greatly in legume content (11 to 100%) and, consequently, in chemical composition.

As a basis for possible revision of class limits, the relative importance of various mixtures, together with a consideration of their chemical composition or feeding value, would seem to be important criteria.

Classes of hay were grouped according to respective grades in this study, and a comparison was made of the average chemical composition for each grade in *(1)* predominantly legume hay classes and *(2)* predominantly grass hay classes. Considering hay classes that averaged over 50% legumes (see table 3), the U. S. No. 1 hay was significantly higher than U. S. No. 2 hay in crude protein and ether extract, and significantly higher than U. S. No. 3 hay in ash and nitrogen-free extract. The percentage of crude fiber in U. S. No. 1 hay was lower than U. S. No. 2 which, in turn, was lower than U. S. No. 3 hay. Differences between U. S. No. 2 and No. 3 hay were small except in the afore-mentioned case of crude fiber and in the case of nitrogen-free extract where the content of U. S. No. 3 hay was significantly lower.

In hay classes averaging less than 50% legumes, small differences were present. However, the numerical grades were significantly lower than sample grade hay in crude fiber. Further, the percentage of nitrogen-free extract was highest in U. S. No. 1 and No. 2 hay. Differences in crude protein, ether extract, and ash were not significant.

The chemical composition of various grades of hay reflects the general superiority of the higher grades. This is particularly true for hays having a substantial percentage

Table 2.—Average chemical composition of 16 hay classes (90% dry matter).

Class of hay	Chemical composition				
	Crude protein	Ether extract	Crude fiber	Ash	Nitro-free extract
	%	%	%	%	
(Predominantly legumes)					
Alfalfa Hay	15.2	2.0	31.8	6.8	34.2
Alfalfa Clover Mixed Hay	14.8	2.6	30.4	6.5	35.7
Clover Hay	12.6	2.4	30.2	6.6	38.2
Alfalfa Light Grass Mixed Hay	14.9	2.4	31.0	6.8	34.9
Alfalfa Light Timothy Mixed Hay	13.7	2.2	32.6	6.6	34.9
Clover Timothy Mixed Hay	10.7	2.3	32.1	5.7	39.2
Alfalfa Heavy Grass Mixed Hay	14.2	2.3	30.6	6.9	36.0
Mixed Hay	11.2	2.0	32.1	6.1	38.6
Alfalfa Heavy Timothy Mixed Hay	11.2	2.1	33.0	5.9	37.8
LSD 0.05	1.1	N.S.	1.7	0.5	1.2
0.01	1.5	N.S.	N.S.	0.7	1.6
(Predominantly grass)					
Timothy Heavy Clover Mixed Hay	9.3	2.1	32.6	5.6	40.4
Timothy Light Alfalfa Mixed Hay	8.8	2.0	35.7	5.4	38.1
Timothy Light Clover Mixed Hay	8.3	2.0	33.8	5.5	40.4
Grass Hay	9.6	2.1	31.7	6.3	40.3
Timothy Hay	6.3	2.0	35.6	4.9	41.2
Timothy Light Grass Mixed Hay	7.0	2.1	34.6	5.2	41.1
Timothy Heavy Grass Mixed Hay	6.8	1.9	34.8	5.2	41.3
LSD 0.05	1.1	N.S.	1.7	0.7	0.8
0.01	1.5	N.S.	2.4	N.S.	1.0

Table 3.—Average chemical composition of the several grades from 16 classes of hay (90% dry matter).

Grade	Crude protein	Ether extract	Crude fiber	Ash	Nitrogen-free extract
	%	%	%	%	%
(Predominantly legume classes)					
U. S. No. 1	14.1	2.6	28.8	6.5	38.0
U. S. No. 2	12.8	2.2	31.1	6.3	37.6
U. S. No. 3	12.6	2.2	33.8	6.1	35.3
Sample	13.1	2.0	32.5	6.8	35.6
LSD 0.05	0.7	0.3	1.1	0.4	0.8
0.01	N.S.	N.S.	1.5	0.5	1.0
(Predominantly grass classes)					
U. S. No. 1	7.8	2.2	33.4	5.2	41.4
U. S. No. 2	7.9	2.0	33.6	5.2	41.3
U. S. No. 3	8.1	2.0	33.8	5.6	40.5
Sample	8.3	2.0	35.6	5.7	38.4
LSD 0.05	N.S.	N.S.	1.3	N.S.	0.8
0.01	N.S.	N.S.	1.8	N.S.	1.1

of legumes. As previously shown, a higher protein and mineral content along with a lower crude fiber content characterized the legume hay classes. The U. S. Standards for grading further differentiated the hays for the above chemical feed constituents. Hay classes low in legume content were shown to be high in nitrogen-free extract, a valuable energy source. The grades of low legume classes, although failing to differentiate hays affectively for most nutrient determinations, did further distinguish hays high in nitrogen-free extract.

The chemical composition of Sample grade hay often compared favorably with higher grades in crude protein and mineral content but was generally low in ether extract, nitrogen-free extract and higher in fiber. The musty and moldy condition or the contamination usually characterizing Sample grade hay makes it undesirable for animal feeding. Presence of mustiness or mold automatically results in a hay being assigned the "Sample" grade. The presence of excess amounts of foreign material reduces the grade regardless of other characteristics of the hay.

The results of this study are in substantial agreement with findings of actual feeding trials in which high grade hay was found to be superior to the lower grades (3, 4, 5, 6, 11).

As pointed out by Archibald *et al.* (2) feeding trials are the most reliable means of determining the nutritive value of hays. However, the time and expense involved in evaluating hays by this method make it imperative that some rapid index of hay quality be developed.

As shown by this study, the U. S. Hay Standards can be used to obtain a good indication of the chemical composition or the feed value of hay. Individually the factors of grading are often subjected to criticism. However, when considered together, the color, leafiness, foreign material content, condition as to soundness, and stage of maturity of hay will provide a rapid indication of the quality of a lot of hay. As suggested by Gordon (3), a point system, placing varying emphasis on the above factors, may strengthen the standards.

SUMMARY

Hay samples were collected from 10 dairy farms in each of 8 New Jersey counties over 4 winter feeding periods as part of an overall hay survey and hay quality study. Samples were officially graded and analyzed chemically for feeding constituents. The relationship between the grades of hay and their chemical composition was studied.

A total of 1,775 hay samples was tabulated under 16 official hay classes. The average chemical composition of various classes was shown to vary widely. Decrease in legume content of classes resulted in a general decrease in crude protein and ash, and an increase in crude fiber and nitrogen-free extract.

For predominantly legume hay classes, U. S. No. 1 hay was generally superior to U. S. No. 2 and/or U. S. No. 3 hay in crude protein, ether extract, ash, and nitrogen-free extract, and lower in crude fiber content. In predominantly grass hay classes, differences between numerical grades were limited to a higher nitrogen-free extract content of U. S. No. 1 and U. S. No. 2 hays.

Sample Grade hay for all classes often compared favorably with higher grades in crude protein and ash content but was generally low in ether extract and nitrogen-free extract, and high in crude fiber.

The U. S. Hay Standards can be used for obtaining good indication of the chemical composition or feed value of hay. Some classes of hay, however, were found to overlap in terms of feed value based on chemical composition. The need for re-defining of classes is thus indicated.

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Behavior of Alfalfa Varieties in the Valley of Mexico[1]

Roderic E. Buller, J. B. Pitner, and Miguel Ramirez[2]

IRRIGATED alfalfa is the most important forage crop for the dairy industry of Mexico. About 136,000 acres of alfalfa are scattered throughout the Republic, with the heaviest concentration of alfalfa fields occurring within numerous milksheds such as the one surrounding Mexico City in the heart of the Valley of Mexico. Alfalfa is utilized very intensively. It is either grazed or cut and fed green from 8 to 12 times a year, depending upon the area. Very little alfalfa hay or silage is made. Because of the importance of alfalfa, one of the objectives of the joint forage program of the Secretaría de Agricultura y Ganadería and The Rockefeller Foundation has been to determine the best adapted varieties. Considerable emphasis has been given to variety testing in the Valley of Mexico.

Geographically the Valley of Mexico is in the tropics, but because of the high elevation of approximately 7,600 feet the climate is temperate. Seasons, however, do prevail. During the summer the temperature averages 63.8°F. and during the winter it averages 57.1°F. Frosts of short duration are common at this altitude during the wintertime, and the nights are quite cool. The rainy season occurs approximately from June through October, and the remainder of the year is dry. During the rainy season, irrigation is not normally necessary for alfalfa, but during the dry season it is essential if production is to be maintained.

MATERIALS AND METHODS

A replicated alfalfa variety trial was established at the Experimental Station in Chapingo, Mexico, in the summer of 1952 to determine the comparative behavior of eleven alfalfa varieties. The trial was established on a soil of high fertility at a seeding rate of about 25 pounds per acre. The test consisted of two popular Mexican varieties called Oaxaca and Apaseo; Valenciana, a variety from Spain; and eight varieties from the United States representing both the non-hardy and winter-hardy types. The non-hardy varieties were California Common, Hairy Peruvian, Southwest Common, Arizona Chilean, African, and Caliverde. The winter-hardy varieties were Ranger and Kansas Common. The varieties African, Hairy Peruvian, Valenciana, Apaseo, and Oaxaca are commonly grown at the present time in the Valley of Mexico. The dimensions of the individual plots were 2.5 by 10 meters, from which a swath 1 by 10 meters was harvested with a power mower in order to determine yield. During the first harvest year, all varieties were cut six times and yields recorded in green weight. During the second harvest year, all varieties were cut eight times except Ranger and Kansas Common, which were cut only seven times because of lack of production during the winter. Facilities were available during the second year to permit the handling of moisture samples and expression of yields on a 12% moisture basis. Besides yield, data such as recovery after cutting, height at cutting, maturity, survival, and susceptibility to disease were recorded.

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RESULTS AND DISCUSSION

Forage yields.—Forage yields, by cuttings, for 2 harvest years are presented in tables 1 and 2. In the first harvest year, 1952–53, there were no significant differences between varieties for total season yield at the 5% level of probability although yields ranged from 37.31 to 46.70 tons of green alfalfa per acre. In the second year, 1953–54, there were significant differences between varieties for total season yield.

Apaseo and Valenciana were the two highest yielding varieties in both years. In the second year these two varieties produced significantly more forage than the winter-hardy varieties—Ranger and Kansas Common—and the non-hardy varieties Arizona Chilean, Hairy Peruvian, African, and Southwest Common. Ranger and Kansas Common yielded more than Arizona Chilean, Hairy Peruvian, African, and Southwest Common in the second year although these differences were not significant at the 5% level of probability.

The analyses of variance revealed that the interaction of varieties × cuts was highly significant for both harvest years. This indicated that the varieties performed differently at the different cuts. Figure 1 graphically illustrates the seasonal distribution of forage production of some representative varieties during the second harvest year. There was a general tendency for production of all varieties to decline during the winter, primarily because of cool temperatures. Ranger and Kansas Common were dormant during winter and therefore produced very little forage during this time of the year. Consequently no cutting was made

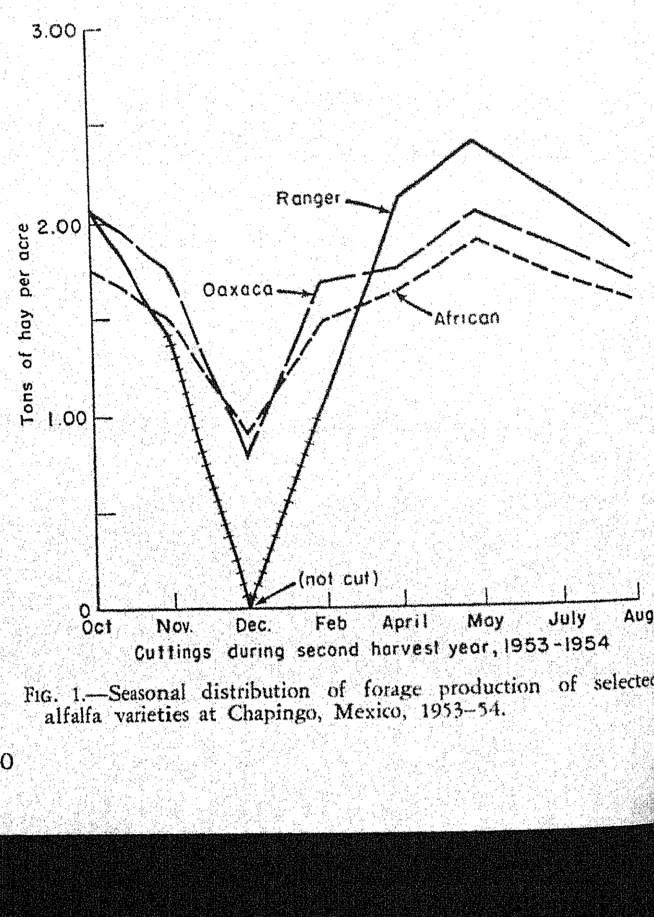

FIG. 1.—Seasonal distribution of forage production of selected alfalfa varieties at Chapingo, Mexico, 1953–54.

of these varieties in December 1953. In contrast, the non-hardy varieties were productive during winter. It is interesting to note that the winter-hardy varieties outyielded many of the non-hardy varieties in spring and summer. These winter-hardy varieties appeared to be very vigorous in spring in comparison to many of the non-hardy varieties, which appeared to be in a weakened condition. Winter production is very important in the Valley of Mexico because there is a general shortage of forage at this time of the year. For this reason winter-hardy varieties are not being recommended at the present time for the Valley of Mexico, although they have good spring and summer production and excellent persistence of stand.

Plant and growth characteristics.—As can be seen in table 3, the 11 varieties included in this test were classified into 3 groups based primarily on maturity, recovery after cutting, and winter habit. When cutting was delayed, the non-hardy alfalfas exhibited about 80% flowering, the hardy types about 31%, and the intermediate types about 42%.

Recovery after cutting was most rapid for the non-hardy alfalfas, although during spring and summer there was not much difference between any of the varieties. During the winter, frosts commonly caused top injury to the non-hardy alfalfas. The winter-hardy varieties, because of their dormant tendencies, remained short and green throughout the winter.

During the rainy season most of the alfalfa grown in the Valley of Mexico is severely infected with leaf spot caused by *Pseudopeziza medicaginis* (Lib.) Sacc. and downy mildew caused by *Peronospora trifoliorum* D.By. As the plant matures, infection gets progressively worse until many of the leaves begin to fall, resulting in low quality forage. The severity of these leaf diseases has led the farmers to cut their alfalfa frequently and in a very immature stage

Table 1.—Forage yield of alfalfa varieties during first harvest year (1952–53) at Chapingo, Mexico (expressed in tons of green matter per acre).

Variety	Average yield per cutting						Total season production
	1 Sept. 10, 1952	2 Feb. 10, 1953	3 Apr. 1, 1953	4 May 15, 1953	5 June 26, 1953	6 Aug. 12, 1953	
Apaseo	4.32	5.58	7.03	8.79	11.35	9.63	46.70
Valenciana	5.33	4.31	6.58	8.03	11.57	8.95	44.78
California Common	5.43	5.33	6.34	7.88	11.42	8.29	44.67
African	5.11	5.37	6.53	8.46	10.91	8.03	44.42
Caliverde	3.57	4.33	6.40	7.99	10.28	10.88	43.44
Arizona Chilean	4.27	5.43	5.95	7.90	10.60	8.09	42.23
Oaxaca	2.86	4.66	5.68	7.36	10.46	9.37	40.39
Hairy Peruvian	4.06	4.85	5.92	7.77	9.89	7.63	40.11
Kansas Common	4.26	1.66	5.93	7.67	10.64	9.24	39.40
Southwest Common	3.71	4.73	5.63	7.15	8.86	7.66	37.74
Ranger	4.23	1.31	4.73	6.42	10.66	9.97	37.31
Average	4.29	4.33	6.06	7.76	10.60	8.88	41.93
F values for varieties	4.76**	15.44**	2.38*	2.14	1.86	6.34**	2.14

* Significant at 5% level.
** Significant at 1% level.

Table 2.—Forage yield of alfalfa varieties during second harvest year (1953–54) at Chapingo, Mexico (expressed in tons of hay per acre—12% moisture).

Variety	Average yield per cutting								Total season production
	1 Oct. 2, 1953	2 Nov. 12, 1953	3 Dec. 24, 1953	4 Feb. 25, 1954	5 Apr. 20, 1954	6 May 27, 1954	7 July 12, 1954	8 Aug. 28, 1954	
Apaseo	2.08	1.74	0.94	1.70	1.95	2.12	1.87	1.77	14.18
Valenciana	2.07	1.69	0.91	1.68	1.86	2.16	1.89	1.83	14.10
Caliverde	2.25	1.61	0.59	1.62	1.83	1.88	1.92	1.90	13.60
Oaxaca	2.07	1.73	0.79	1.67	1.73	2.03	1.83	1.65	13.51
California Common	1.86	1.64	0.86	1.71	1.82	1.97	1.87	1.54	13.27
Ranger	2.08	1.43	not cut	1.09	2.09	2.37	2.05	1.85	12.97
Arizona Chilean	1.77	1.66	0.83	1.64	1.75	1.94	1.70	1.50	12.79
Kansas Common	1.94	1.47	not cut	1.13	2.07	2.32	1.86	1.87	12.66
Hairy Peruvian	1.60	1.54	0.87	1.74	1.69	1.85	1.70	1.47	12.46
African	1.79	1.51	0.89	1.43	1.61	1.89	1.69	1.54	12.35
Southwest Common	1.60	1.60	0.88	1.46	1.71	1.84	1.56	1.48	12.13
Average	1.92	1.60	0.84	1.53	1.83	2.03	1.81	1.67	13.09
F values for varieties	17.61**	4.92**	6.58**	2.44*	3.91**	1.97	3.46**	4.75**	5.44**

* Significant at 5% level.
** Significant at 1% level.

Table 3.—Plant and growth characteristics of alfalfa varieties at Chapingo, Mexico.

Variety	Stand survival*	Height (cm.)	Disease†	Maturity	Recovery after cutting	Winter habit	Resistance to frost
Apaseo	1430	65.00	8.00	Early	Rapid	Active	No
Oaxaca	1037	72.13	8.50	Early	Rapid	Active	No
Hairy Peruvian	949	75.25	9.25	Early	Rapid	Active	No
African	869	74.63	8.50	Early	Rapid	Active	No
Arizona Chilean	1044	75.25	7.50	Early	Rapid	Active	No
California Common	1067	75.63	8.25	Early	Rapid	Active	No
Southwest Common	952	69.75	9.25	Early	Rapid	Active	No
Valenciana	1538	69.25	7.00	Interm.	Interm.	Semi-dormant	Average
Caliverde	1743	70.63	4.75	Interm.	Interm.	Semi-dormant	Average
Kansas Common	1714	66.75	8.50	Late	Slow	Dormant	Yes
Ranger	2183	66.00	6.75	Late	Slow	Dormant	Yes
F values for varieties	25.41**	4.39**	3.20**				

* Number of stems per square meter after 2 years.
† 1 = least susceptible; 10 = most susceptible.
** Significant at 1% level.

of growth. Caliverde has shown the most resistance to these diseases.

The stands of many of the non-hardy alfalfa varieties weakened considerably after 2 years. This tendency was noted particularly for the varieties Hairy Peruvian, African, and Southwest Common. The varieties Oaxaca, Arizona Chilean, and California Common also showed signs of weakening. The varieties Apaseo, Valenciana, Caliverde, Ranger, and Kansas Common have exhibited good persistence of stand. The two winter-hardy alfalfas showed a tendency to develop large crowns, from which arose a large number of stems, in contrast to the non-hardy alfalfas which develop small crowns.

SUMMARY AND CONCLUSIONS

The comparative behavior of 11 alfalfa varieties of diverse origin and type was determined for 2 harvest years in the Valley of Mexico at an elevation of about 7,600 feet above sea level. Of these, two local varieties, Apaseo and Oaxaca; a Spanish variety, Valenciana; and two non-hardy introduced varieties, African and Hairy Peruvian, are commonly grown at the present time in the Valley of Mexico.

In the first harvest year, 1952–53, the average season total yield was 41.93 tons of green alfalfa per acre. The average season total yield in the second year, 1953–54, was 13.09 tons of alfalfa hay (12% moisture) per acre.

Among the varieties commonly grown in the Valley of Mexico at present, Apaseo, Valenciana, and Oaxaca were superior to African and Hairy Peruvian. The winter-hardy varieties, Ranger and Kansas Common, were unproductive during the winter but highly productive in spring and summer. Of the newly introduced varieties, Caliverde appeared to be the most outstanding, primarily because of its superior resistance to leaf spot and downy mildew. Its total annual yield was not significantly better than the local varieties.

The non-hardy alfalfas were early maturing, quick recovering, winter active, highly susceptible to top injury from frosts and generally weak in stand persistence. The winter-hardy varieties were late maturing, slow recovering, winter dormant, frost resistant, and excellent in stand persistence. An intermediate growth type was defined for the varieties Caliverde and Valenciana.

The Competitive Relationship of Merion Bluegrass as Influenced by Various Mixtures, Cutting Heights, and Levels of Nitrogen[1]

F. V. Juska, J. Tyson, and C. M. Harrison[2]

THE increasing emphasis placed on the production of fine turf for lawns, golf courses, parks, and other recreational areas has led to many unanswered problems as to how such turf could be best established. The advent of Merion, a new strain of bluegrass, intensified the problems largely because of scarcity and high price of seed. With the release of this new turfgrass, information as to seeding rate, cutting heights, fertilizer practices, and its reaction in mixtures was necessary to its proper establishment.

The present investigation was conducted in the greenhouse *(1)* in an attempt to answer the question as to what percentage of Merion bluegrass seed is necessary in a seed mixture in order to obtain satisfactory establishment of the bluegrass, and *(2)* to study the influence of cutting and fertilizer treatments on the establishment and development of Merion bluegrass foliage, roots, and rhizomes.

REVIEW OF LITERATURE

Several investigators (4, 5, 6, 8) have shown that an increase in the severity of defoliation caused a highly significant decrease in the production of roots, rhizomes, and top growth. As early as 1897, Crozier (1) of Michigan reported that orchardgrass clipped 7 times during a 45-day period yielded only 29% as much dried forage as did comparable material cut once at the conclusion of the experiment. Graber (3) found that the simple expediency of setting the lawn mower to cut "high" produced a thick turf free of weeds in contrast to one which was thin and weedy due to close clipping at the same frequency.

In studies with quackgrass, Johnson and Dexter (7) pointed out that the repeated removal of top growth, previously stimulated with nitrogen, resulted in the plant drawing on its organic reserves for new plant growth. This treatment resulted in carbohydrate starvation and eventual death of the plant.

In a study of the competitive nature of Kentucky bluegrass, Chewings fescue, domestic ryegrass and redtop, not subject to cutting treatments, Erdmann and Harrison (2) compared the growth of individual grasses when sown in mixtures with their growth when sown alone. Domestic ryegrass inhibited the growth of Kentucky bluegrass, Chewings fescue, and redtop. Redtop inhibited the growth of Kentucky bluegrass and Chewings fescue but not to the same extent as did domestic ryegrass.

Morrish and Harrison (10) in a study on wear resistance of various grasses and grass legume mixtures found that domestic ryegrass had completely disappeared in a mixture of Kentucky bluegrass, redtop, and Chewings fescue after 2 to 3 years.

EXPERIMENTAL PROCEDURE

Merion bluegrass, a strain of Kentucky bluegrass *(Poa pratensis)*, creeping red fescue *(Festuca rubra* var. *genuina)*, redtop *(Agrostis alba)*, and domestic ryegrasses *(Lolium multiflorum* and *L. perenne)* in pure species and various mixtures were used for this experiment conducted at Michigan State University.

The seedings were made in the greenhouse in quartz sand in 10-inch clay pots at the rate of 1 pound per 1,000 square feet on Nov. 17, 1953. In order to insure a uniform distribution, the seed was mixed with a small amount of sand before sowing. The cultures consisted of the 4 species sown alone and 16 different mixtures.

Twenty cultures, 1 each of the 4 species and 16 mixtures were put together as a group. Five such groups were set up and one group each received one of the following management treatments: *(a)* three-quarters inch cutting, high nitrogen; *(b)* three-quarters inch cutting, low nitrogen; *(c)* 2 inch cutting, high nitrogen; *(d)* 2 inch cutting, low nitrogen; and *(e)* no cutting with medium fertility. A randomized split plot design with three replications was used. This made a total of 300 cultures.

Stand counts were made on Jan. 8 and Feb. 10 respectively on 2 groups of 20 cultures each receiving the "no cutting" treatment (table 1). The number of plants of each species was determined by separation and counting a portion of the culture.

The cultures were watered as needed and, after emergence, supplied with a three-salt nutrient solution. The amount of nutrient solution per culture was regulated with a fair degree of accuracy by adjusting the shut-off valve from the supply tank to a counting rate so that the desired number of cubic centimeters of nutrient solution could be applied weekly to all cultures. After Feb. 1, 1954, differential amounts were applied to the cultures receiving the high and low nitrogen. Beginning on Dec. 21, 1953, a solution of ammonium sulfate was applied from time to time to the cultures receiving high nitrogen in amounts varying from 50 to 250 pounds of ammonium sulfate per acre.

The sand in which the cultures were growing was occasionally flushed with water to prevent excessive accumulation of salts.

An attempt was made to keep the cultures receiving low nitrogen within a range of 1 to 0 ppm. and the high nitrogen level at 25 or more ppm. of soluble nitrogen as was indicated by the Spurway and Lawton (10) green tissue test. Weekly tissue tests were taken to maintain the two levels of nitrogen.

Except for the "no cutting" cultures, defoliation of the grass at the designated heights of 2 inches and of three-quarters of an inch was initiated on Dec. 12, 1953.

The top growth of the cultures subjected to cutting treatments were hand separated by species at harvest time, March 20–25, as they were clipped from the roots. The sand was carefully washed away from the roots and rhizomes by a stream of water from a garden hose nozzle. Washing was done over a three-sixteenth inch mesh wire screen. Oven-dry weights were recorded for top growth, roots, and rhizomes. In order to secure more accurate results, the roots were oven-dried and then ashed at 600° F. in a muffle furnace. Root weights were obtained by subtracting the weights of ash and sand from the oven-dried weights.

EXPERIMENTAL RESULTS

A stand count of the initial seedling establishment was made Jan. 8, 1954, on one culture of the four species seeded alone and one each of the 16 mixtures.

The second group of 20 cultures of "no cutting" treatment was harvested and stand counts were made on Feb. 10, 1954. In comparing the stand counts of Merion bluegrass for the two dates, it was found that there was an increase in the number of plants in some mixtures and a decrease in others. The results of the second stand counts indicate that redtop, domestic ryegrass, and creeping red fescue each exerted a definite depression on the number of Merion bluegrass plants established. It became very difficult to count individual plants accurately because of tillering. Since the amount of tillering and growth from rhizome tips would have made counting more difficult with the passage of time, the stand-count method was discontinued. The tops of the remainder of the cultures were hand separated as to species, and weights were recorded on an oven-dry basis.

[1] Contribution from the Departments of Soil Science and Farm Crops, Michigan Agr. Exp. Sta., East Lansing, Mich. Journal Article No. 1786, the Michigan Agr. Exp. Sta. Part of a thesis submitted by the senior author at Michigan State University in partial fulfillment of the requirements for the Ph.D. degree. Received June 24, 1955.

[2] Research Agronomist, U.S.D.A., Beltsville, Md., and Professors of Soil Science and Farm Crops, respectively.

Table 1.—The influence of three grass species on the stand counts of Merion bluegrass under "no cutting" treatment harvested Jan. 8–9, and Feb. 10, 1954.

Mixtures, in percent	Stand counts Jan. 8				Stand counts Feb. 10–11			
	Merion bluegrass	Fescue	Redtop	Rye-grass	Merion bluegrass	Fescue	Redtop	Rye-grass
1. Merion bluegrass, 100	332	—	—	—	668	—	—	—
2. Creeping red fescue, 100	—	164	—	—	—	132	—	—
3. Redtop, 100	—	—	1,850	—	—	—	2,008	—
4. Domestic ryegrass, 100	—	—	—	68	—	—	—	72
5. Bluegrass, 90; fescue, 10	292	12	—	—	156	24	—	—
6. Bluegrass, 70; fescue, 30	176	56	—	—	212	40	—	—
7. Bluegrass, 50; fescue, 50	204	84	—	—	136	76	—	—
8. Bluegrass, 30; fescue, 70	160	152	—	—	172	92	—	—
9. Bluegrass, 10; fescue, 90	52	138	—	—	16	124	—	—
10. Bluegrass, 90; redtop, 10	280	—	240	—	400	—	224	—
11. Bluegrass, 90; ryegrass, 10	312	—	—	8	352	—	—	8
12. Bluegrass, 70; redtop, 30	288	—	728	—	152	—	1,008	—
13. Bluegrass, 70; ryegrass, 30	284	—	—	20	304	—	—	20
14. Bluegrass, 50; redtop, 50	264	—	864	—	184	—	1,248	—
15. Bluegrass, 50; ryegrass, 50	132	—	—	20	212	—	—	28
16. Bluegrass, 50; fescue, 30; redtop, 10, ryegrass, 10	144	42	240	8	136	72	256	16
17. Bluegrass, 30; fescue, 30; redtop, 20; ryegrass, 20	152	72	440	8	136	24	144	16
18. Bluegrass, 30; fescue, 50; redtop, 10; ryegrass, 10	144	72	280	8	40	80	224	8
19. Bluegrass, 70; fescue, 10; redtop, 10; ryegrass, 10	208	32	200	14	344	8	176	6
20. Bluegrass, 80; fescue, 10; redtop, 5; ryegrass, 5	320	48	90	4	424	16	100	4

The final weights for tops, roots, and rhizomes for the "no cutting" treatments are given in table 2. Some time after emergence, the vigorous growth habit of domestic ryegrass was apparent as indicated by thick coarse stems and broad leaves. Many of the ryegrass culms headed out previous to harvest, but this was not the case with the other three grasses. The largest weight of top growth was produced by domestic ryegrass, 46.1 g., followed by redtop with 29.3 g. Merion bluegrass and creeping red fescue tops weighed about the same, 26.2 and 26.7 g. respectively. Redtop in mixture with Merion bluegrass had the most depressing effect on the production of Merion bluegrass tops and rhizomes. It will be noted in the cultures which contained 50% of creeping red fescue, redtop and domestic ryegrass, respectively, that creeping red fescue had the least depressing effect on Merion bluegrass rhizome yields followed by ryegrass and redtop.

Table 2.—The influence of three grass species on the yields of Merion bluegrass tops and rhizomes under "no cutting" treatment and harvested on March 25, 1954.

Mixtures, in percent	Weight of tops, in grams				Weight, in grams	
	Merion bluegrass	Fescue	Redtop	Ryegrass	Roots Total	Rhi-zomes
1. Merion bluegrass, 100	26.2	—	—	—	16.3	5.6
2. Creeping red fescue, 100	—	26.7	—	—	24.0	—
3. Redtop, 100	—	—	29.3	—	18.6	—
4. Domestic ryegrass, 100	—	—	—	46.1	28.5	—
5. Bluegrass, 90; fescue, 10	17.8	6.0	—	—	15.8	3.3
6. Bluegrass, 70; fescue, 30	16.0	8.4	—	—	22.5	5.3
7. Bluegrass, 50; fescue, 50	5.3	17.5	—	—	23.3	1.6
8. Bluegrass, 30; fescue, 70	5.5	20.2	—	—	26.9	1.8
9. Bluegrass, 10; fescue, 90	7.7	25.3	—	—	20.9	.5
10. Bluegrass, 90; redtop, 10	17.0	—	9.5	—	16.6	2.5
11. Bluegrass, 90; ryegrass, 10	17.3	—	—	23.9	19.1	2.5
12. Bluegrass, 70; redtop, 30	4.1	—	22.7	—	15.9	.5
13. Bluegrass, 70; ryegrass, 30	10.2	—	—	32.6	28.2	2.3
14. Bluegrass, 50; redtop, 50	1.2	—	24.2	—	21.7	.3
15. Bluegrass, 50; ryegrass, 50	4.1	—	—	40.1	24.8	1.0
16. Bluegrass, 50; fescue, 30; redtop, 10; ryegrass, 10	7.7	9.8	9.3	11.4	22.8	1.2
17. Bluegrass, 30; fescue, 30; redtop, 20; ryegrass, 20	1.1	3.1	18.7	10.4	21.7	.1
18. Bluegrass, 30; fescue, 50; redtop, 10; ryegrass, 10	3.2	8.8	7.9	13.5	18.8	.5
19. Bluegrass, 70; fescue, 10; redtop, 10; ryegrass, 10	6.6	2.2	10.3	21.0	16.9	.5
20. Bluegrass, 80; fescue, 10; redtop, 5; ryegrass, 5	23.8	2.6	5.1	5.0	16.2	4.7

Table 3.—The influence of mixture, two levels of nitrogen and two heights of cut on the yield of Merion bluegrass rhizomes.*

Mixtures, in percent	Treatments			
	Nitrogen—High		Nitrogen—Low	
	2 in. cut	¾ in.	2 in. cut	¾ in.
1. Merion bluegrass, 100	0.191	0.005	1.471	0.127
2. Creeping red fescue, 100	—	—	—	—
3. Redtop, 100	—	—	—	—
4. Domestic ryegrass, 100	—	—	—	—
5. Bluegrass, 90; fescue, 10	.160	.012	1.412	.047
6. Bluegrass, 70; fescue, 30	.173	.006	.980	.067
7. Bluegrass, 50; fescue, 50	.115	.025	.868	.086
8. Bluegrass, 30; fescue, 70	.154	.002	.908	.058
9. Bluegrass, 10; fescue, 90	.055	.003	.079	.028
10. Bluegrass, 90; redtop, 10	.019	.000	.321	.003
11. Bluegrass, 90; ryegrass, 10	.084	.052	1.120	.024
12. Bluegrass, 70; redtop, 30	.022	.000	.067	.000
13. Bluegrass, 70; ryegrass, 30	.113	.002	1.012	.050
14. Bluegrass, 50; redtop, 50	.002	.000	.294	.000
15. Bluegrass, 50; ryegrass, 50	.081	.005	.785	.082
16. Bluegrass, 50; fescue, 30; redtop, 10; ryegrass, 10	.005	.000	.217	.000
17. Bluegrass, 30; fescue, 30; redtop, 20; ryegrass, 20	.000	.000	.072	.008
18. Bluegrass, 30; fescue, 50; redtop, 10; ryegrass, 10	.028	.000	.351	.000
19. Bluegrass, 70; fescue, 10; redtop, 10; ryegrass, 10	.037	.000	.348	.000
20. Bluegrass, 80; fescue, 10; redtop, 5; ryegrass, 5	.135	.018	.770	.067
Averages†	.081	.007	.651	.038

* Average weight in grams of three replications made on an oven dry basis.
** Highly significant difference between treatment averages.

Production of Clippings

The average production of clippings per culture, regardless of mixture, calculated on an oven-dry basis for the 15-week period for high nitrogen, high cutting was 16.0 g.; high nitrogen, low cutting, 9.8 g.; low nitrogen, high cutting, 3.5 g.; and low nitrogen, low cutting, 3.9 g.

Both domestic ryegrass and creeping red fescue yields were reduced by close clipping more than were redtop and Merion bluegrass. In all cases, the cultures receiving a high level of nitrogen and cut at a 2-inch height produced more clippings than the cultures under high nitrogen and low cutting treatments. Redtop and Merion bluegrass under low nitrogen produced more clippings when cut at three-quarters of an inch than at 2 inches. Opposite results were obtained for domestic ryegrass and creeping red fescue in that these grasses yielded a smaller quantity of clippings under low nitrogen and low cutting.

Production of Roots

The production of total roots was definitely inhibited by low cutting and high nitrogen treatments. The average production of roots per culture was as follows: 5.1 g., high nitrogen, high cutting; 1.9 g., high nitrogen, low cutting; 11.5 g., low nitrogen, high cutting and 4.5 g., low nitrogen, low cutting. The cultures receiving a low level of nitrogen and high cutting produced the greatest quantity of roots. In every case, these cultures produced more roots than did the cultures receiving high nitrogen and high cutting. Each of the cultures under low nitrogen and low cutting produced a greater root weight than those under high nitrogen and low cutting treatments.

Production of Rhizomes

The weights of the bluegrass rhizomes produced under the two levels of nitrogen and two heights of cutting are given in table 3. Merion bluegrass rhizome production was reduced by both the high nitrogen and low cutting treatments. The low nitrogen and high cutting treatment yielded the largest quantity of rhizomes, whereas the rhizome yield under high nitrogen and low cutting was practically negligible.

The rhizomes produced by the Merion bluegrass were definitely inhibited in the cultures in which the mixtures contained 10, 30, and 50% of redtop.

Production of Top Growth

The top growth of the 16 mixtures was hand separated by species. Oven-dry weights were recorded for all four species. The difference in the amount of top growth of Merion bluegrass produced for the two levels of nitrogen and two heights of cutting when alone and in mixture were highly significant. Table 4 gives the oven-dried weights for the Merion bluegrass tops after separation from the other species.

The response of Merion bluegrass to cutting and no cutting treatments and levels of nitrogen is illustrated in figure 1. Culture D, which received high nitrogen and 2-inch cutting, produced a large amount of foliage desirable for turf purposes and also an adequate supply of roots and rhizomes to carry the grass through adverse conditions. On the other hand, culture C receiving the same cutting height but a low level of nitrogen produced a much larger quantity of roots and rhizomes, but a lack of adequate top growth for good turf.

Table 4.—The influence of mixture, two levels of nitrogen and two cutting heights on the yield of Merion bluegrass top growth at the end of the experiment.*

Mixtures, in percent	Treatments			
	Nitrogen—High		Nitrogen—Low	
	2 in. cut	¾ in.	2 in. cut	¾ in.
1. Merion bluegrass, 100	17.98	9.15	10.67	5.66
2. Creeping red fescue, 100	——	——	——	——
3. Redtop, 100	——	——	——	——
4. Domestic ryegrass, 100	——	——	——	——
5. Bluegrass, 90; fescue, 10	14.05	6.57	7.17	5.05
6. Bluegrass, 70; fescue, 30	13.38	6.90	6.27	4.30
7. Bluegrass, 50; fescue, 50	11.57	7.22	5.25	3.77
8. Bluegrass, 30; fescue, 70	6.92	3.84	3.92	2.25
9. Bluegrass, 10; fescue, 90	3.33	3.37	1.48	1.59
10. Bluegrass, 90; redtop, 10	8.81	4.65	5.86	3.05
11. Bluegrass, 90; ryegrass, 10	10.73	7.60	9.42	3.99
12. Bluegrass, 70; redtop, 30	4.61	1.19	2.60	2.29
13. Bluegrass, 70; ryegrass, 30	12.61	8.32	7.37	4.85
14. Bluegrass, 50; redtop, 50	1.74	.45	1.23	.66
15. Bluegrass, 50; ryegrass, 50	7.19	.759	6.29	3.93
16. Bluegrass, 50; fescue, 30; redtop, 10; ryegrass, 10	5.25	2.57	2.85	1.55
17. Bluegrass, 30; fescue, 30; redtop, 20; ryegrass, 20	1.75	.60	1.24	.66
18. Bluegrass, 30; fescue, 50; redtop, 10; ryegrass, 10	3.96	1.18	1.63	1.23
19. Bluegrass, 70; fescue, 10; redtop, 10; ryegrass, 10	5.67	3.37	3.46	1.69
20. Bluegrass, 80; fescue, 10; redtop, 5; ryegrass, 5	13.84	8.57	10.32	4.76
Averages **	8.43	4.89	5.12	3.02

* Average weight in grams of three replications made on an oven dry basis.
** Highly significant differences between treatment averages and mixtures.

Figure 2 illustrates the treatments which favored the production of creeping red fescue. The brown roots indicate a predominance of fescue in cultures C and E. No cutting and 2-inch cutting treatments and a low level of nitrogen favored the growth of creeping red fescue. Cultures A and D received a high level of nitrogen and favored the production of Merion bluegrass. In this 50–50 mixture a change in the levels of nitrogen determined which species predominated.

A mixture of 50% redtop inhibited both the top growth and rhizome production of Merion bluegrass. (See figure 3). It is doubtful whether Merion bluegrass could compete successfully in this mixture regardless of cutting heights or nitrogen treatments applied.

Figure 4 illustrates Merion bluegrass cultures in mixture with 50% ryegrass. Merion bluegrass was able to compete successfully under all treatments except for "no cutting". Low cutting was detrimental to the production of ryegrass foliage. The cultures receiving high nitrogen and low cutting (A) inhibited the growth of ryegrass to the greatest extent.

A comparison was made between mixtures receiving a low level of nitrogen with high cutting and their effect on the reduction of Merion bluegrass rhizomes. In the mixtures containing 10% of creeping red fescue, redtop, and domestic ryegrass respectively, it was found the redtop inhibited rhizome production to the greatest extent. A similar comparison of cultures containing 30 and 50% each of the 3 species in mixture with Merion bluegrass resulted in a reduction of rhizomes in a descending order, beginning with redtop, domestic ryegrass and creeping red fescue.

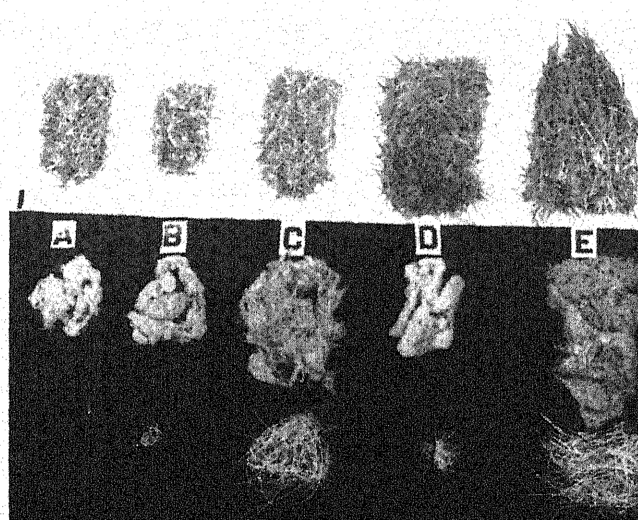

FIG. 1.—Merion bluegrass at final harvest on Mar. 25, 1954. First row, foliage; second row, roots; third row, rhizomes. A.—High nitrogen, low cutting; B.—Low nitrogen, low cutting; C.—Low nitrogen, high cutting; D.—High nitrogen, high cutting; E.—No cutting, average level of fertility.

DISCUSSION

A comparison of top growth and rhizomes produced on a weight basis for the last group of no cutting cultures harvested on Mar. 25, indicated that redtop was somewhat more competitive with Merion when 30 or 50% of redtop seed was used than was either creeping red fescue or domestic ryegrass seeded at the same rates. Of the last two

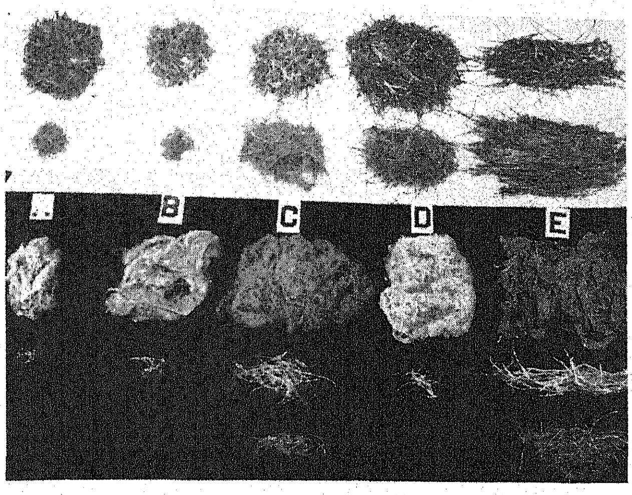

FIG. 2.—Merion bluegrass and creeping red fescue at final harvest on Mar. 25, 1954. A 50–50 mixture of Merion bluegrass and creeping red fescue. Note the rhizomes produced by the red fescue at the bottom of the photograph. First row, Merion bluegrass foliage; second row, fescue foliage; third row, mass of roots of mixture; fourth row, Merion bluegrass rhizomes; and fifth row, fescue rhizomes.

A.—High nitrogen, low cutting; B.—Low nitrogen, low cutting; C.—Low nitrogen, high cutting; D.—High nitrogen, high cutting; E.—No cutting and average fertility.

species, red fescue appeared to be less competitive than ryegrass with Merion bluegrass.

Clipping the grass at either of the two cutting heights inhibited the development of both roots and rhizomes. A study of the tables and photographs shows that the grasses under the no cutting treatment produced a greater quantity of roots and rhizomes. Clipping reduced the photosynthetic area of the plants and decreased the production of roots and rhizomes. The reduction of subterranean growth indicates a reduction of available organic reserves for use by the plant in new growth or during adverse growing conditions.

The high level of nitrogen stimulated top growth at the expense of root and rhizome production. These nitrogen-stimulated plants apparently were using carbohydrates more rapidly than they were being replaced by photosynthetic activity. A combination of both low cutting and a high nitrogen level reduced the subterranean growth to the greatest extent.

Redtop was the most competitive of the three species used in mixture with Merion bluegrass (figure 3). A pound of redtop has a greater number of seeds than does Merion bluegrass, therefore a 50–50 mixture would contain considerably more redtop than Merion bluegrass seeds. A greater number of plants, sod forming habit, more rapid germination, and the ability of redtop to withstand close cutting all tend to account for its greater competitive ability.

Domestic ryegrass also germinates rapidly but competition from numbers of plants is reduced since the ratio of seeds per pound is approximately 1 to 9 of Merion bluegrass. The bunchy type of growth and inability to withstand close cutting also tend for decreased competition with other grasses. Even though domestic ryegrass germinated sooner, grew more rapidly, and was coarser in texture than Merion bluegrass, it was not as competitive as redtop when sown on a percentage weight basis (figure 4).

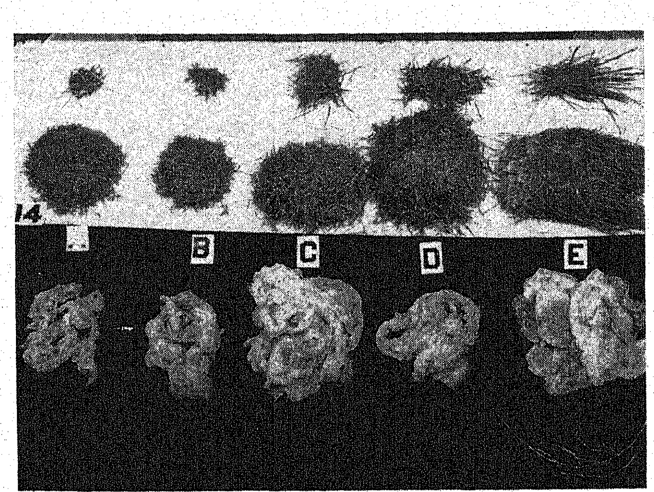

FIG. 3.—Merion bluegrass and redtop at final harvest on Mar. 25, 1954. A 50–50 mixture of Merion bluegrass and redtop showing tops, roots and rhizomes. Note lack of rhizomes for all treatments except the "no cutting". First row, Merion bluegrass foliage; second row, redtop foliage; third row, root masses of mixture; fourth row, Merion bluegrass rhizomes.

A.—High nitrogen, low cutting; B.—Low nitrogen, low cutting; C.—Low nitrogen, high cutting; D.—High nitrogen, high cutting; E.—No cutting and average fertility.

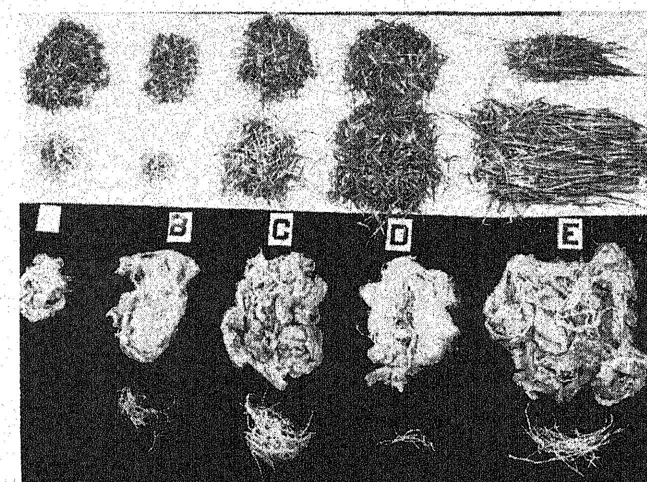

FIG. 4.—Merion bluegrass and domestic ryegrass at final harvest on Mar. 25, 1954. A 50–50 mixture of Merion bluegrass and domestic ryegrass. This mixture did not reduce rhizome production as severely as did a 50% mixture of Merion bluegrass and redtop. First row, Merion bluegrass foliage; second row, domestic ryegrass foliage; third row, root masses of mixture; and fourth row, Merion bluegrass rhizomes.

A.—High nitrogen, low cutting; B.—Low nitrogen, low cutting; C.—Low nitrogen, high cutting; D.—High nitrogen, high cutting; E.—No cutting, average fertility.

Creeping red fescue and Merion bluegrass germinated and grew approximately at the same rate. The ratio of seeds per pound is about 1 of creeping red fescue to 4 of Merion bluegrass. Equal rates of growth, less seed, and the inability of creeping red fescue to withstand close cutting are some factors that account for its being the least competitive with Merion bluegrass.

Except for quick cover, there was no apparent advantage for using either redtop or domestic ryegrass in mixture with Merion bluegrass. Creeping red fescue in a mixture

with bluegrass may be of value where soils are variable in fertility and droughtiness. Merion bluegrass seeded alone produced the best appearing turf.

SUMMARY

A study was made to determine the competitive behavior of Merion bluegrass as influenced by various mixtures containing red fescue, redtop and domestic ryegrass when subjected to two levels of nitrogen, two heights of cutting and no cutting with medium fertility.

1. The greatest yield of clippings was produced by the cultures supplied with high nitrogen and cut at 2 inches.
2. High nitrogen and low cutting treatments inhibited root and rhizome production to the greatest extent.
3. In the production of Merion bluegrass top growth, redtop had the most depressing effect followed by domestic ryegrass. Creeping red fescue was the least competitive of the three grasses used with Merion bluegrass.
4. Merion bluegrass competed favorably with redtop when not over 10% redtop was used in the mixture and a high level of nitrogen maintained.
5. Merion bluegrass competed favorably with ryegrass when 50% was used in the mixtures, especially under high cutting and high nitrogen treatments.
6. Merion bluegrass in mixture with creeping red fescue varied in its competitive behavior; Merion bluegrass predominated under a high level of nitrogen; while creeping red fescue predominated when a low level of nitrogen was maintained.
7. The best appearing turf was produced when Merion bluegrass was seeded alone and maintained under a high level of nitrogen.

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Estimates of Heritability in Hops, *Humulus lupulus* L.[1]

K. R. Keller and S. T. Likens[2]

ALTHOUGH the production of hops in the United States has been an important industry since 1800, limited attention has been directed toward varietal improvement by hybridization. The hop plant, *Humulus lupulus* L., is a long-lived dioecious perennial which is propagated vegetatively from rhizome sections. The bulk of the hop acreage, which is confined primarily to the irrigated sections of Washington, Oregon, California, and Idaho, is planted for the most part of three varieties. Two additional varieties recently introduced from England are also in commercial production on a small acreage. Since the varieties of hops now grown in the United States leave much to be desired relative to production, disease and quality characteristics, a more intensified breeding program may be justifiable. Estimates of heritability and the advance to be expected by applying selection pressure within a population of experimental hop lines for such factors as yield, sidearm length, percentages of the total soft resin, alpha acid, and beta fraction as well as for the chemical composition of leaf blades, may be useful in designing an effective breeding program.

Estimates of heritability were computed for a number of clonally propagated experimental lines from several replicated yield trials to determine the progress that might be expected in conducting a breeding program on hops in the Willamette Valley of Oregon.

REVIEW OF LITERATURE

Various methods for estimating heritability in plants have been presented. Weber (10) suggested that the best estimate of environmental variance for computing the heritability of characters in an inter-specific cross of soybeans was the cube root of the product of the variances of the P_1, P_2, and F_1 populations. Mahmud and Kramer (7) used the square root of the sum of the variances of the two non-segregating parents of the F_2 population to estimate environmental variance in soybeans. Burton (2) working with pearl millet, estimated environmental variance as the variance of the F_1. McDonald, *et al.* (8) and later Kalton, *et al.* (6), used the variance between propagules of a clone (V_{s0}) as an estimate of the environmental variance and subtracted it from the variance of the S_1 population (V_{s1}) in the following formula to estimate heritability in orchardgrass and bromegrass:

$$\frac{V_{s1} - V_{s0}}{V_{s1}} \times 100.$$

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Burton and DeVane (3) computed estimates of heritability in Tall Fescue on a single plot basis and on a replicated plot basis. They computed the total genetic variance from the mean squares for clones and error in the regular analysis of variance by separating out the variance components for V_e and V_g where $V_e + nV_g$ represented the expectation of the clone mean square. They suggested that this method of computing total genetic variances has merit in that *(a)* it does not depend upon the assumption that environmental variance is equal for the segregating and non-segregating populations, and *(b)* it reduces appreciably the amount of genotype × environment variance carried in the estimate of genetic variance.

Burton and DeVane (3) also presented formulas for computing estimates of the expected gain from selection (S) on a single plot and replicated plot basis assuming the selection of the top 5% of the population.

MATERIALS AND METHODS

Three replicated yield trials, each consisting of a number of clonally propagated experimental hop lines with a check variety, were grown in 5-hill plots near Corvallis, Oreg. The trials were designated as (a) an early maturity group, (b) a late maturity group, and (c) an intermediate maturity group. The design of each experiment was a randomized block with 5 replications. All of the experimental lines in these trials were selected and clonally increased from individual plants which appeared to offer promise as the foundation stock for a new variety. Trials (a) and (b) were planted in 1951, whereas trial (c) was planted in 1953. Three years' yield data were available from trials (a) and (b). The two former trials each contained 12 experimental lines and a check variety, whereas trial (c) was made up of 27 experimental lines plus 2 check varieties. Heritability estimates were computed following the procedure outlined by Burton and DeVane (3) for the characters in which there were significant differences among lines and for which there was only a single observation per plot. Where the number of observations are more than one per plot, the formula for estimating heritability H becomes $V_g / (V_g + V_e + V_s)$, where V_s is the expectation of the variation among samples within a plot. The formula for estimating heritability H on a replicated plot basis involving more than one sample per plot is $V_g / (V_g + \frac{V_e}{n} + \frac{V_s}{kn})$

where n is the number of replications and k is the number of samples per plot. The expected gain from selection S, involving more than one observation per plot, was computed on the single plot and replicated plot mean basis, assuming the selection of the top 5% of the population using the following formulas:

$$S \text{ (single plot basis)} = s V_g / \sqrt{V_g + V_e + V_s}$$

$$S \text{ (replicated plot basis)} = s V_g / \sqrt{V_g + \frac{V_e}{n} + \frac{V_s}{nk}}$$

where s = 2.06 for 5% of the population saved.

The genetic variance was derived from the mean squares for lines, experimental error, and sampling error in the regular analysis of variance by separating out the variance components according to the following formulas:

$V_s + k V_e + k n V_g$ = the expectation of the line mean square
$V_s + k V_e$ = the expectation of the error (lines × replications) mean square
V_g = the total genetic variance
V_s = the expectation of the sampling error
k = the number of samples per plot
n = the number of replications.

Estimates of heritability and the expected gain from selection were calculated for 3 years of yield data and 1 year of data for sidearm length, and the percentages of the total soft resin and beta fraction for group (a). Comparable estimates were made for 3 years of yield data and 1 year of data for sidearm length for group (b). Estimates of heritability and the expected gain from selection were computed on yield, sidearm length, the percentages of the total soft resin, alpha acid, and beta fraction, and leaf blade content of total phosphorus, potassium, calcium, organic nitrogen, and nitrate nitrogen for group (c). Since no significant differences were noted among the lines within a trial for moisture content, either harvest weights or dry weights have been used in computing the yield analyses. Leaf blade analyses for total phosphorus and potassium were made for each of two dates during the growing season. Two samples were collected from each plot for all of the leaf blade determinations, which added a sampling error to each analysis of variance.

Chemical analyses of strobiles for soft resin, alpha acid, and beta fraction were made as outlined by Bullis and Alderton (1). A sulfuric-nitric-perchloric acid digest of leaf blade material was employed for the determination of phosphorus by the method of Fiske and Subbarow (4) and potassium and calcium was determined by flame photometry. Organic nitrogen was determined by the Kjeldahl-Cunning-Arnold method (9) and nitrate nitrogen was found by the method of Johnson and Ulrich (5).

EXPERIMENTAL RESULTS

Various types of data from replicated clonal propagules for a number of experimental hop lines within a breeding program may be used to compute estimates of heritability as well as the advance to be expected by applying various levels of selection pressure within a population. Although the genetic variance, V_g, may contain variance due to dominance and epistatic effects, the expected gain values from selection should be appropriate since the crop is asexually propagated. Genetic constants for several measurements, using a single observation per plot, taken from 3 replicated clonal propagule trials in experimental hop lines were computed using the method presented by Burton and DeVane (3). Where more than one sample per plot was involved, the modified formulas were used. The F values for lines in the analysis of variance for each character measured exceeded the 1% level of significance, suggesting that there were real differences among the lines. The results from the analyses of the data for the computed genetic constants for the several measurements are presented in table 1.

The heritability estimates presented in table 1 indicate that, in general, the characters are highly heritable. It may be noted that the heritability estimates have been computed on a single plot or sample basis as well as a replicated basis. In examining table 1, it should be remembered that heritability estimates for the leaf blade determinations of phosphorus, potassium, nitrogen, and calcium were based on 2 samples per plot and sidearm length on 5 observations per plot for each of the 5 replications, whereas all other factors were represented by a single sample per replication. Additional replications or samples increase the magnitude of the estimates of heritability but reduce the range among these estimates as compared to a single sample basis.

The data which are of interest in these studies are the genetic coefficient of variation and the expected gain in percent of the mean, which was computed on a replicated plot basis. These data are indicative of the advance or progress that may be expected by selecting for these characters within each of the experimental trials. For example, in the intermediate maturity group, it was estimated that when selecting the top 5% of the population, yield may be

Table 1.—Genetic constants for several measurements taken from three replicated clonal propagule trials on experimental hop lines at Corvallis, Oreg., 1952–54 inclusive.

Character	Mean $\bar{x}$	Genetic variance (V_g)	Genetic C.V. ($\sqrt{V_g} \times 100$ / $\bar{x}$)	Heritability: Single plot basis	Heritability: Replicated basis	Expected gain (S) from selection on: Single plot basis	Expected gain (S) from selection on: Replicated basis	Expected gain in percent of the mean‡
(a) Early maturity group								
1952 yield (D.W.)*	17.06	8.60	17	0.58	0.88	4.59	5.64	33.0
1953 yield (D.W.)	19.30	3.85	10	.28	.67	1.84	2.81	14.5
1954 yield (D.W.)	17.99	10.05	18	.68	.92	5.40	6.25	34.7
1954 sidearm length	46.70	121.80	24	.52	.95	16.33	22.14	47.4
1953 total soft resin content	15.52	1.55	8	.58	.87	0.82	1.23	7.9
1953 beta fraction	10.78	0.64	7	.64	.90	1.32	1.56	14.5
(b) Late maturity group								
1952 yield (H.W.)†	60.24	279.67	28	.72	.90	29.32	33.20	55.1
1953 yield (D.W.)	16.19	14.45	24	.62	.88	6.15	7.39	45.6
1954 yield (H.W.)	59.25	130.83	19	.54	.86	17.33	21.78	36.8
1954 sidearm length	49.62	157.31	25	.50	.95	18.29	25.16	50.7
(c) Intermediate maturity group								
1954 yield (H.W.)	86.81	346.13	21	.69	.92	31.80	36.70	42.3
Sidearm length	58.84	58.27	13	.23	.46	7.48	13.87	23.6
Total soft resin content	15.68	4.86	14	.65	.90	3.67	4.32	27.5
Alpha acid	5.15	1.69	25	.83	.96	2.45	2.62	50.8
Beta fraction	10.68	1.42	11	.61	.88	1.91	2.32	21.7
Phosphorus ppm. (June)	3382.59	213,938.57	13	.40	.81	606.59	856.83	25.3
Phosphorus ppm. (July)	1960.92	63,186.94	13	.58	.83	394.79	472.69	24.1
Potassium (% D.W.) June	1.16	.0168	11	.35	.70	0.16	0.22	19.0
Potassium (% D.W.) July	0.96	.0276	17	.57	.81	0.26	0.31	32.3
Ogranic nitrogen (% D.W.) July	3.07	.0571	8	.50	.77	0.35	0.43	14.0
Nitrate nitrogen ppm. (July)	988.58	102,639.07	32	.59	.83	505.38	601.30	60.8
Calcium (% D.W.) June	2.92	.10	11	.25	.55	.32	.48	16.4

* Dry weight.
† Harvest weight.
‡ Replicated plot basis.

Table 2.—Correlation coefficients between characters measured among lines for the intermediate maturity yield trial, Corvallis, Oreg., 1954.

	Harvest weight	Sidearm length	Total nitrogen	Nitrate nitrogen	Total phosphorus	Potassium	Calcium	Alpha acid	Beta fraction	Total soft resin content
Harvest weight	——	0.28	−0.62**	−0.31	−0.39	−0.28	−0.02	0.11	−0.16	−0.10
Sidearm length		——	−.62**	−.04	−.54**	.12	.32	−.16	−.03	−.12
Total nitrogen			——	.40*	.79*	.40	.07	−.21	.12	.03
Nitrate nitrogen				——	.10	.42*	.03	−.40*	.01	−.17
Total phosphorus					——	.41*	−.34	−.21	.21	.10
Potassium						——	−.13	−.16	−.03	.12
Calcium							——	.16	−.06	.00

* Significance at the 5% level.
** Significance at the 1% level.
Note: r values were computed on a mean line basis with 27 degrees of freedom.

increased by 42%, sidearm length by 24%, and the values for the resin and leaf blade analyses between 14 and 61% depending upon the characters in question. These results are of particular interest to the plant breeder in that they estimate the latitude for progress that exists within that particular group of lines. Selection within the various experimental groups presented in table 1 appears promising for each of the characters investigated. This is of particular interest since these lines were originally selected on the basis of desirable agronomic characters, disease resistance, and quality as measured by the percentages of the total soft resin, alpha acid, and beta fraction.

A point of further interest in table 1 is the relatively close agreement among the expected gains in the last column for yields among years within group (a) and (b) with the exception of the 1953 yield in group (a). A similar agreement is also indicated between the phosphorus content of leaf blades for the June and July collections.

An examination of the genetic coefficients of variation for the characters presented in table 1 suggests that, in general, there is relatively wide variation between lines for each character. This information alone is encouraging to the plant breeder since it indicates the possibilities that exist within the several groups. Since several characters

were measured in the intermediate maturity group, correlation coefficients have been computed between all possible combinations to determine the association between the phenotypic characters. For example, a high correlation between harvest weight and total nitrogen as determined from leaf blade analyses might be utilized as an effective technic in reducing the expenditure of time and funds in evaluating lines developed in the breeding program. The results from the analyses of these computations are presented in table 2.

The results from the computations of the correlation coefficients presented in table 2 indicate that although several are significant, none is of sufficient magnitude to be of any real value from a predictive standpoint. Actually, most of the correlation coefficients indicate little or no association between the characters studied.

DISCUSSION

The production, marketing, and utilization of hops are highly specialized industries. Hop growers are primarily interested in yield per acre. Dealers, on the other hand, are concerned with marketing of the baled product the value of which is determined, for the most part, on physical characteristics such as seeds, leaves and stems, moisture content, color, and aroma. The utilization of hops in the brew is largely dependent upon physical characteristics as well as the soft resins in the strobiles which are bitter and impart this taste to the beer or wort. The plant breeder, therefore, is confronted with a minimum of three selection criteria which must receive consideration in the development of a new variety of hops. Since the crop is a perennial and is rather costly to establish, these factors are of real importance. The yielding ability of a hop line may be evaluated accurately in experimental field trials. An evaluation of the physical characteristics and brewing qualities are somewhat more difficult. The "preservative value" or "brewing value" formulae which have been employed by the English workers but which have been of limited use in the United States, are calculated on the basis of the percentages of alpha acid and beta fraction. The relative importance ascribed to alpha or beta, however, varies depending upon the investigator. Although the factors with which the various industries are concerned may not be easily defined, they will play an important role in the acceptance of a new variety.

The information in tables 1 and 2 merely indicates the latent possibilities that exist for several characters, as well as the association between these factors. It is realized that the results presented here are far from complete. They are intended merely to introduce the potentialities that may exist for investigation of other factors.

SUMMARY AND CONCLUSIONS

Estimates of heritability of several characteristics were computed using data from each of three replicated clonal propagule trials involving a number of selected experimental hop lines grown near Corvallis, Oreg. Total genetic variance, V_g, environmental variance, V_e, estimates of heritability, H, on a single and replicated plot basis, and the expected gain (S) from selection assuming the selection of the top 5% of the population, were computed.

The results from the analyses of the data for each of the characters studied indicated that there were highly significant differences among the lines. These results suggested that there were differences among the lines in their superiority for the specific factors considered.

The average expected gains in percent of the mean when selecting the top 5% of the population on a replicated plot basis for yields, sidearm length, and the percentages of total soft resin content and beta fraction indicated that an advance of 37, 40, 18 and 18%, respectively, over the population mean could be expected. The expected gain in percent of the mean for the percentage of alpha acid was 50.8%, whereas estimates for leaf blade content of total phosphorus, potassium, calcium, organic nitrogen, and nitrate nitrogen varied from 14 to 61%.

Correlation coefficients computed between the various characters indicated that, in general, the factors were independent and therefore could not be utilized for predictive purposes.

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Wheat Stem Sawfly Damage in Four Spring Wheat Varieties as Influenced by Date of Seeding[1]

F. H. McNeal, M. A. Berg, and P. Luginbill, Jr.[2]

A LOSS of 2,251,073 bushels of wheat was reported for Montana in 1952 as a result of the activity of the wheat stem sawfly, *Cephus cinctus* Nort. (1). Because wheats have not been found which give satisfactory sawfly resistance under all conditions, other methods of control have been suggested. Munro *et al.* (5) present limited data to show that delayed seeding is effective in preventing damage. Davis *et al.* (2) report that wheat planted after May 20 will escape sawfly damage. Early maturing varieties have been considered in the hope that injury would be avoided, but Eckroth and McNeal (3) found such varieties to be very susceptible to sawfly cutting.

Losses in yield due to sawfly activity are caused by *(1)* reduction in kernel weight due to larval tunneling in the stems, and *(2)* loss of wheat when the stem is cut and falls to the ground (4, 5, 6, 7). Seamans *et al.* (7) report losses of 10% in kernel weight due to sawfly tunneling, while Munro *et al.* (5) report losses of slightly over 9% from the same cause.

The present study reports the loss in kernel weight of 2 solid and 2 hollow-stemmed spring wheat varieties when seeded on 3 dates and subjected to heavy sawfly infestation.

MATERIALS AND METHODS

Two solid-stemmed varieties of spring wheat, Rescue and Merit–Pilot × Rescue (B49–90), and 2 hollow-stemmed varieties, Thatcher and Merit–Pilot × Henry (C.I. 12733), were planted on 3 dates under conditions of heavy sawfly infestation on dryland at Choteau, Mont., in 1953 and 1954. Dates of seeding in 1953 were May 6, May 15 and June 17, and in 1954 they were May 6, May 17, and May 31.

In both years the 12 treatments (4 varieties × 3 planting dates) were grown in a randomized complete block design with 4 replications of 3-row plots seeded in 10-foot rows 12 inches apart. All data were obtained from 5 feet of the center row of each plot in 1953 and from 2 feet of the center row of each plot in 1954, starting 1 foot from the edge of the plot.

Plants from the designated area in each plot were pulled at harvest time and stored. The first two dates of seeding were pulled on Sept. 11, 1953, and Sept. 1, 1954, while the third date was pulled on Sept. 16, 1953, and Sept. 22, 1954. Wheat from these plants was then used as a basis for determining sawfly losses.

Each stem from the 1953 planting was examined to determine if it had been tunneled by a sawfly larva or if it had escaped infestation. The stems which had been tunneled were separated into the categories, stems cut by sawfly and stems not cut. The uncut stems were further separated on the basis of whether they had been tunneled in 1, 2, 3, or 4 internodes. Some missing categories were obtained in the third date of planting because of little sawfly tunneling in the uncut stems.

Stems from the 1954 crop were separated on the basis of stems cut by sawfly, stems tunneled but not cut, and stems not tunneled. Some missing categories were obtained for the class, stems not tunneled, due to extremely heavy sawfly tunneling and cutting.

Kernel weight was obtained by weighing 200 kernels for each category in each replication. In a few cases, 200 kernels were not available so smaller numbers were weighed and the weights calculated to a 200-kernel weight basis.

The number of kernels per head was obtained by averaging the kernels from 20 heads for each category from each replication. In a few cases, 20 heads were not obtained so an average of those available was used.

Sawfly cutting percentages were determined by dividing the number of cut stems by the total number of stems.

RESULTS AND DISCUSSION

Kernel Weight

A comparison of kernel weights from cut stems with those from stems tunneled in 1, 2, 3, or 4 internodes was made in 1953 (table 1). Data from the June 17 planting were omitted from the analysis because of so many missing categories. The *F* test showed differences in kernel weights between varieties and dates of planting, but no differences were detected between kernel weights from the five classes. This indicates that the weight of grain from a cut stem could be used as an index to determine the grain weight from tunneled stems, regardless of the number of internodes tunneled. Such results seem reasonable since the stem is not cut until the larva has finished its feeding.

Combined data on kernel weights for 1953 and 1954 were analyzed on the basis of stems cut by sawfly and those not tunneled (tables 2, 3, and 4). Again the third date was omitted from the analysis because of missing categories (table 2).

There was generally a decrease in kernel weight as a result of sawfly tunneling. The only exceptions to this were C.I. 12733 and Thatcher seeded on the second date in 1953 and Thatcher seeded on the second date in 1954.

Significant differences in kernel weights were obtained between the main effects: first two dates of seeding, years, sawfly damage and varieties (tables 3 and 4). None of the interactions was at a significant level. Losses in kernel

Table 1.—Average weight in grams of 200 kernels of wheat from stems cut and stems tunneled by sawfly larvae in a date of seeding experiment in 1953.

Variety	Stems cut	Number of internodes tunneled in uncut stems			
		1	2	3	4
	Planted May 6				
C.I. 12733	5.26	5.67	5.73	5.56	5.63
Thatcher	4.98	5.08	5.01	5.23	5.24
B49–90	5.12	5.18	4.72	5.05	4.93
Rescue	5.16	5.08	5.11	5.29	5.13
Average	5.13	5.25	5.14	5.28	5.23
	Planted May 15				
C.I. 12733	5.07	5.14	5.22	5.32	5.40
Thatcher	5.00	5.31	3.92	5.03	5.03
B49–90	4.66	4.29	4.49	5.03	6.45
Rescue	4.90	4.18	4.58	3.85	5.13
Average	4.91	4.73	4.55	4.81	5.50
	Planted June 17				
C.I. 12733	5.11	4.11	4.50	4.77	5.33
Thatcher	4.56	—	—	4.96	4.38
B49–90	—	5.04	—	—	—
Rescue	4.65	—	—	5.90	—

[1] Joint contribution of the U.S.D.A. and the Montana Agr. Exp. Sta. Paper No. 357 Journal Series. Received Aug. 1, 1955.

[2] Associate Agronomist and Agricultural Aid, Field Crops Research Branch, and Entomologist, Entomology Research Branch, A.R.S., U.S.D.A. The authors express appreciation to H. W. Somsen of the Entomology Research Branch for assistance in planting the material.

Table 2.—Average weight in grams of 200 kernels of wheat from stems cut and stems not tunneled by sawfly larvae in a date of seeding experiment.

Variety	1953			1954		
	Stems cut by sawfly	Stems not tunneled by sawfly	Loss or gain in wt.*	Stems cut by sawfly	Stems not tunneled by sawfly	Loss or gain in wt.*
			%			%
	Planted May 6			Planted May 6		
C.I. 12733	5.26	5.56	−5.40	4.34	4.76	− 8.82
Thatcher	4.98	5.23	−4.78	3.74	4.73	−20.93
B49-90	5.12	5.26	−2.66	3.46	4.49	−22.94
Rescue	5.16	5.36	−3.73	4.22	4.31	− 2.09
Average	5.13	5.35	−4.11	3.94	4.57	−13.78
	Planted May 15			Planted May 17		
C.I. 12733	5.07	5.03	+0.80	3.82	4.33	−11.78
Thatcher	5.00	4.99	+0.20	3.62	3.22	+12.42
B49-90	4.66	4.92	−5.28	3.56	3.70	− 3.78
Rescue	4.90	4.94	−0.81	4.17	4.49	− 7.13
Average	4.91	4.97	−1.21	3.79	3.94	− 3.81
	Planted June 17			Planted May 31		
C.I. 12733	5.11	5.13	−0.39	3.70	——	——
Thatcher	4.56	4.68	−2.99	3.27	4.02	−18.66
B49-90	——	4.51	——	3.27	4.27	−23.42
Rescue	4.65	4.90	−5.10	3.68	4.31	−14.62
Average	4.77	4.90	−2.65	3.41	4.20	−18.81

* Refers to loss or gain in weight of kernels from cut stems compared with weight of kernels from stems not tunneled.

Table 3.—Average weight of 200 kernels for the components dates, years and sawfly damage in 1953 and 1954.

Item	Date of seeding		Years		Sawfly damage	
	First	Second	1953	1954	Stems cut	Stems not cut or tunneled
Weight in grams	4.75	4.40	5.09	4.06	4.44	4.71
L.S.D. (P=0.05)	0.20		0.20		0.20	

Table 4.—Average weight of 200 kernels for varieties in 1953 and 1954.

Item	Varieties			
	C.I. 12733	Rescue	Thatcher	B49-90
Weight in grams	4.77	4.69	4.44	4.40
L.S.D. (P=0.05)	0.29			

weight were greatest in the first date of seeding, except that losses were extremely high in the third date of seeding in 1954 (table 2). Even in 1953, losses were higher in the third date of seeding than in the second. A possible explanation may be that plants from later seedings are infested in a younger stage of development, and the sawfly larvae may actually do more feeding in vital tissues of such plants than in plants that are more fully developed.

The losses in kernel weight in 1953 were much less than those in 1954. Weather data for the 2 years show that precipitation for the 1953 crop year was 16.69 inches compared with 7.94 inches in 1954, while the 1945–54 average was 12.29 inches. It is possible that losses would be aggravated more by some abnormal condition such as sawfly tunneling in an exceptionally dry year than in a year when more normal growing conditions existed.

On the basis of these data it appears that in a year when available moisture is above normal, the loss in kernel weight due to sawfly activity might approach 5%. In an exceptionally dry year such as 1954, the losses in kernel weight may run to 20% or higher.

Kernels Per Head

The data in 1954 show that the sawfly larvae were most active in the largest stems of the wheat plant. The stems which were not tunneled had 2.8 kernels per head less than those which were cut by the sawfly larvae (table 5). Seamans *et al.* (7) found that the female sawfly selects the largest and best developed stems in which to oviposit. Data from the present study verifies these results.

Twenty heads were not available from all varieties for the category, stems not tunneled. In the case of Thatcher in the first date of seeding, only six heads were available from all replications. However, these data consistently indicate that the sawfly larvae did more tunneling in the largest stems, which usually have the largest heads.

Table 5.—Average number of kernels from 20 heads from cut stems, tunneled stems, and stems not tunneled by sawfly larvae in a date of seeding experiment in 1954.

Variety	Number of kernels per head		
	Stems cut	Stems tunneled	Stems not tunneled
Planted May 6			
C.I. 12733	23.0	23.3	20.0
Thatcher	25.1	21.0	27.8
B49-90	24.0	24.3	21.0
Rescue	25.8	24.0	23.4
Average—May 6 =	23.6 kernels per head		
Planted May 17			
C.I. 12733	20.6	20.8	13.0
Thatcher	24.7	17.3	19.0
B49-90	19.0	18.9	16.8
Rescue	22.1	22.8	20.9
Average—May 17 =	19.7 kernels per head		
Average—May 6 and May 17	23.0	21.6	20.2
Planted May 31			
C.I. 12733	22.0	16.6	—
Thatcher	21.5	19.5	19.4
B49-90	19.3	19.0	17.6
Rescue	20.5	20.8	21.6

L.S.D. (P = 0.05) for comparing average number of kernels per head from stems cut, stems tunneled and stems not tunneled for the first 2 dates = 2.11 kernels.

L.S.D. (P = 0.05) for comparing average number of kernels per head of the May 6 planting with that of the May 17 planting = 1.72 kernels.

Sawfly Cutting

While records were not obtained on the number of sawfly eggs which failed to hatch, it is clear from the percentage of tunneled stems shown in table 6 that hollow-stemmed C.I. 12733 had much more tunneling in 1953 than solid-stemmed Rescue. There was little difference between Thatcher and B49-90 in the percentage of tunneled stems, showing that among solid-stemmed wheats B49-90 is not as effective as Rescue in controlling sawfly larval feeding.

Significant differences were obtained between the two hollow and either or both of the solid-stemmed varieties in the percentage of tunneled stems which were cut by sawfly larvae in 1953, but the hollow-stemmed varieties had similar averages. B49-90 had a lower average than Rescue, but this was due primarily to a zero reading in the third date of planting. This indicates that solid-stemmed wheats are less likely to be cut than hollow-stemmed wheats, even though they have been tunneled by sawfly larvae.

There were also significant differences between the solid- and hollow-stemmed wheats in sawfly cutting for the 2 years (table 6). Rescue had the lowest percentage of cutting while C.I. 12733 was the most susceptible to cutting. There was practically no difference in sawfly cutting between Thatcher and B49-90 in 1953 but in 1954 Thatcher was much more susceptible to cutting.

Differences were also obtained between the different dates of seeding in the amount of sawfly cutting. High cutting percentages were obtained on the first two dates of seeding in both 1953 and 1954. Even the May 31 date

Table 6.—Average sawfly tunneling and cutting percentages from a date of seeding experiment in 1953 and 1954.

Variety	% of stems tunneled 1953	% of tunneled stems cut 1953	% sawfly cutting		
			1953	1954	Ave.
Planted May 6, 1953 or May 6, 1954					
C.I. 12733	74.1	88.4	66.1	84.8	75.4
Thatcher	50.0	89.1	44.9	80.4	62.6
B49-90	50.9	88.3	45.2	56.8	51.0
Rescue	37.2	83.2	30.9	23.5	27.2
Average	53.0	87.2	—	—	54.0
Planted May 15, 1953 or May 17, 1954					
C.I. 12733	58.0	91.4	52.7	86.6	69.6
Thatcher	31.8	89.7	28.5	79.3	53.9
B49-90	40.7	76.7	30.9	51.5	41.2
Rescue	32.2	86.7	27.9	20.4	24.2
Average	40.7	86.1	—	—	47.2
Planted June 17, 1953 or May 31, 1954					
C.I. 12733	28.3	78.9	22.0	76.4	49.2
Thatcher	4.9	84.6	4.2	64.3	34.2
B49-90	0.3	0.0	0.0	28.5	14.2
Rescue	0.4	16.7	0.3	37.4	18.8
Average	8.5	45.0	—	—	29.1
Variety average for the 3 dates					
C.I. 12733	53.5	86.2	46.9	82.6	64.7
Thatcher	28.9	87.8	25.9	74.7	50.2
B49-90	30.6	55.0	25.4	45.6	35.5
Rescue	23.3	62.2	19.7	27.1	23.4
L.S.D. (P=0.05) for comparing variety averages	6.7	10.6	—	—	5.5
L.S.D. (P=0.05) for comparing date averages	5.8	9.2	—	—	4.8

of seeding in 1954 gave very high cutting percentages, although the June 17 planting in 1953 reduced the average for the third date far below the average of the other two dates. The relatively high cutting percentages from the third date show that to avoid loss from sawfly, seeding date would need to be postponed until June 1 or later. This is too late in most sawfly areas as losses in yield would usually result from a shortened growing season.

SUMMARY

Two solid-stemmed varieties of spring wheat, Rescue and B49-90, and two hollow-stemmed varieties, Thatcher and C.I. 12733, were planted on three dates under conditions of heavy sawfly infestation on dryland at Choteau, Mont., in 1953 and 1954.

It was found that kernel weight from stems cut by the sawfly could be used as an index to determine the kernel weight from tunneled stems, regardless of whether they had been cut.

Losses in kernel weight due to sawfly tunneling approached 5% in some varieties in 1953, a year when available moisture was above normal. In 1954 when precipitation was more than 4 inches below normal, the loss in kernel weight exceeded 20% in some varieties.

Number of kernels per head shows indirectly that the female sawfly selects the main tillers, or most mature stems available, for oviposition.

Differences obtained between the four varieties in the percentage of tunneled stems which were cut by the sawfly indicated that solid-stemmed wheats are less likely to be cut than hollow-stemmed wheats, even though both have been tunneled by a sawfly larva.

Sawfly cutting was highest in the hollow-stemmed varieties and lowest in the solid-stemmed varieties. The earliest variety, C.I. 12733, was cut the most while Rescue was cut the least.

Later seeding reduced sawfly cutting significantly. However, it is concluded that the seeding date would need to be postponed until after June 1 to escape serious damage from the wheat stem sawfly.

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Student Counseling[1]

AIDS TO EFFECTIVE COUNSELING

Louis M. Thompson[2]

USE OF TEST SCORES AND HIGH SCHOOL GRADES

APTITUDE test scores can be very helpful to the student counselor provided that he has been properly instructed in their use. Where large samples are drawn, there is high correlation between the aptitude scores and performance in college.[3] On the other hand, as one plots the regression of college grades on aptitude scores, he finds the deviation of some individuals to be strikingly great. Therefore, in dealing with an individual, a counselor must always keep in mind the limitations of individual predictions.

Aptitude tests do not measure motivation, and a student with low scores may perform remarkably well because of hard work. Sometimes a student will perform poorly on aptitude tests with the purpose that he will be assigned to a slower section of some course where his competition for grades will be less. Some students are so unfamiliar with the types of tests used that they become tense, and waste much of their time and do more poorly than they should. For these and other reasons a counselor should not assume a student will do poorly in college if his aptitude tests are low. By all means, the counselor should refrain from telling a student that his scores are low. A student with low scores needs additional confidence, and knowing that his scores are low will not help build his confidence in himself.

High aptitude scores are more meaningful in that the student has to have high ability in order to achieve high scores. He may not do well because of lack of interest or motivation. In such a case, it may prove challenging to let the student know that he has more ability than he has demonstrated. Knowledge of his high scores can be a real motivating factor.

Sometimes a student may ask his counselor for his test scores. If the scores are low, the counselor should be most diplomatic and careful in his interpretation. When telling a student that he is in the 10th percentile one would not

[1] Papers presented before Div. XIII, Agronomic Education, American Society of Agronomy, St. Paul, Minn., Nov. 8–12, 1954. Received July 8, 1955.

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[3] The correlation coefficient was 0.48 for 1,520 freshmen who entered Iowa State College in 1946. The ACE psychological examination score was compared to the grade of each student after the first quarter in college. (Unpublished data of Testing Bureau, Iowa State College.)

say "you are in the low 10 percentile"; one might say, "you are in the 10th percentile, which means that you did better than 10 out of 100 who took the test" (and *not* say "90 out of 100 who took the test made a higher score than you did"). Furthermore, low aptitude scores are often associated with slow reading. It is very helpful to the student with low scores if he learns that his rate of reading-speed might be a cause of his low performance on aptitude tests. Any improvement in his reading habits will be reflected in his college work.

A combination of test scores and high school grades provides the best basis for predicting a student's success in college. High grades in high school and high aptitude test scores are expressions of ability and application. Low grades in high school and low aptitude test scores mean that the student will have a struggle in college, and will require considerable motivation in order to pull through successfully.

A flexible freshman curriculum, whereby a schedule is prepared in accordance with the student's capabilities, is particularly helpful to students in agriculture. Many students who do not have the ability to complete a 4-year college program would profit greatly by a year of practical subjects in agriculture before dropping out to become a farm operator. A counselor can use high school grades and aptitude test scores to predict pretty well which students should follow a more practical freshman program.

PRE-COLLEGE COUNSELING

During the past two summers the counselors in Farm Operation in Iowa State College have visited all of their freshmen who were residents of Iowa on their home farms. This is not a recruiting program. The counselors visited only those students who had been admitted to Iowa State College to major in Farm Operation. During the summer of 1954, the two counselors spent a total of 31 days calling on 155 freshmen. They averaged 5 calls per day at a cost of $3.20 per student for travel expense, figuring 5¢ per mile for the automobile. This pre-college counseling program has proved to be of tremendous value. The program has meant as much to parents as to the student. An opportunity is provided for the parents to ask questions and to gain the feeling that the college is interested in their son as an individual. The parents frequently ask about job opportunities for their son in the event that he is unable to start in farming after graduating from college. By the time of the visit the student may have received several letters from social fraternities, and the parents want to know more about them. They appear to ask questions much more readily in their home than parents do who visit our office. They feel that the visit is an expression of personal interest. The public relations value, alone, is great enough to warrant the time and money spent for the program, yet the most important feature is the knowledge the counselor gains about the student that will help later when the time comes for advising him on courses to take and other plans for the future. Farm Operation students must decide eventually as to whether they will earn a certificate for the 2-year program or work toward a B.S. degree in Farm Operation.

The large enrollment (over 400 each year) would require more counselors if the summer visitation program were abandoned. Consequently the program actually represents a saving to the college at the same time it provides for a highly effective means of establishing acquaintance between counselor and counselee. It gives the student confidence in his counselor and, as a consequence, more frequent visits are made to the counselor for assistance with educational and personal problems.

COUNSELING ON A PERSONAL BASIS

T. J. Mann[1]

ALTHOUGH larger institutions of higher learning have attempted to provide education on a mass production basis, students have retained their individuality. The variability among students and student problems necessitates different approaches on the part of the adviser, each on an individual student basis. While it is difficult to prescribe techniques for doing an effective job of advising and counselling, certain basic factors might be considered.

The first prerequisite for effective advising is the establishment of student confidence in an adviser. This necessitates something more than a formal or casual acquaintance between a student and his adviser. In order that an adviser do an effective job, he must be more than a source of a signature essential for the completion of the various steps in registration. A student needs to feel that his adviser has a personal interest in him as an individual.

In many ways an adviser of an agronomy student is in a very favorable position for the establishment of student confidence since both have common interests in problems of crop production and soil management. For example, in North Carolina a majority of the agronomy undergraduates come from tobacco farms. An adviser whose research activities deals with the improvement of tobacco varieties, and the advisee whose financial support is derived from tobacco have common interests in something quite apart from problems of course scheduling.

An advisor may become acquainted with his students in a number of ways:

1. Through visits to a student's farm and in his home before and after that student enrolls in college;

2. Through mutual acquaintances such as county agents, teachers of agriculture, and other agricultural workers;

3. Through active participation in students' extracurricular activities;

4. Other students may frequently aid in the establishment of an acquaintance. When a student has established confidence in an adviser, he may direct fellow students to that adviser.

While there are innumerable ways for an adviser to become acquainted with his students, one of the most effective ways is to have the student visit in the home of his adviser. It helps a student immensely to discover that his adviser, an agronomist, has difficulty in establishing a lawn, that his adviser has children equally as mischievous as their own younger brothers and sisters; and that faculty members, too, must live on budgeted income. Having made such discoveries, the student may take a new look at his adviser and more readily accept him and his advice.

Once an acquaintance has been made and confidence has been established, a good adviser must be sympathetic. He

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must know what other counselling and advising facilities are available to the student and recommend their use when appropriate. He must make a concerted effort to provide real "meat" to the solution of the problem of the troubled student. Above all, an adviser must be available. An administration that recognizes the importance of sound advising and counselling will see that time is provided for the adviser to participate in the various activities proposed above, and in so doing, lay a firm foundation for this vitally important phase of student training and development.

THE OBJECTIVES OF GOOD ADVISING AND COUNSELING

T. H. Gooding[1]

ADVISING or counseling of college students as it is practiced today may be considered a science, whereas 20 or 25 years ago it was more an art. This does not mean that it has reached a stage of perfection, for there is plenty of room for improvement. Before taking up the objectives in this field, it might not be out of place to mention three aids or prerequisites which may strengthen advising and counseling.

First, the success of a good advising and counseling service largely depends upon the personal qualities and abilities of the people engaged in this work. Theodore H. Copeland, Jr.,[2] lists the pertinent qualities and characteristics of a successful teacher as empathy, enthusiasm, sincerity, and humility. These seem to apply just as well to a successful adviser or counselor. Copeland places empathy as a most important quality in a successful teacher. He defines it as a "mental entering into the feeling or spirit of another person." The successful adviser tends to put himself in the place of the advisee in order to appreciate more fully the situation in which the advisee finds himself.

Copeland states that the teacher who possesses this quality will be regarded by his students as sympathetic, kind, and thoughtful and that he will be sensitive to their problems and needs. If an adviser or counselor possesses these qualities and characterstics, and is willing to study the fundamental procedures involved in advising and counseling so as to improve his techniques, he should make long strides toward success in this field.

Second, while it is important to make the right choices in selecting personnel for advising and counseling work, it is probably just as important to make the work sufficiently remunerative and challenging to hold workers who are successful. A person with qualifications for counseling and advising is likely to be in demand in other areas of educational work as well. Lip service on the part of the administration is not sufficient recognition for these services. Some institutions of higher learning do give recognition for advising and counseling either by an increase in salary or by reducing the teaching load to some extent. But all too few institutions give it proper consideration in comparison with research, teaching, and extension. If a faculty member comes up for advancement in rank, how is advising and counseling rated as compared to the number of journal articles, bulletins, and text books published? The point is that it should have a place in the rating scale for promotion in rank.

As a third aid or prerequisite to successful advising and counseling, a trained psychologist should be employed on the counseling staff. In addition to clinical diagnostic and therapeutic duties, he would help train the younger members for the job of advising and counseling. This course of training would not be given with the hope of making a professional psychiatrist out of each member on the staff. But the members of the staff could be taught to recognize symptoms of emotional illness in their early stages of development. These cases then could be referred to the psychiatrist where the condition could be most easily dealt with.

From the standpoint of sequence, as far as the relationship between the adviser and the advisee is concerned, the first objective in successful advising and counseling is that of getting the advisee off to a right start. This was probably less difficult 20 years ago. The high school curriculum at that time conformed more closely to the course of study as recommended for college preparatory purposes. In recent years there has been a swing toward vocational training. In defense of this trend the high school administrator will contend that since the majority of high school graduates do not attend college, it is believed unwise to sacrifice vocational subjects for college preparatory training. It is not uncommon to find an agricultural college student floundering around trying to remove a deficiency in mathematics. More than likely this student took 3 years of vocational agriculture with the idea of farming after finishing high school. But during his senior year he decided to go to college. Now that he is in college he finds that he is not only deficient in mathematics but that he also sidetracked physics and chemistry for courses in vocational agriculture.

The general run of students who enrolled in institutions of higher learning 20 years ago were more mature than the students now entering colleges and universities. It is now quite common to see boys only 17 years of age enrolling in college.

The prospect of being called into the military service, while not as baffling a problem now for college students as during the Korean conflict, nevertheless remains a disturbing factor.

In addition to the prospect of military service, the lack of preparation in basic subject matter, and the fact that many students coming to college seem immature, there are other factors that make an advising and counseling service necessary. One of the main factors that make college difficult for new students is the great difference that exists between high school and college. A big problem in getting the new college student off to a right start seems to be that of helping him to adjust to the conditions of college life. Possibly the course in orientation should take care of helping bridge this gap between high school and college. It does give a great deal of assistance but not enough. What are some of these differences to which the new student finds it difficult to adjust?

In high school each pupil had a fixed daily program. If a problem arose in connection with a course, he could contact the instructor for help. A good share of his daily preparation was made in the assembly or study hall. Mother and father were available to help select his clothing; they had considerable to say about his choice of companions

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[2] Copeland, Theodore H., Jr. The touch of teaching. Jour. of Nat. Ed. Assoc. 43:416. 1954.

and the type of entertainment in which he participated. But in college he is on his own.

One of the first differences the new student notices in college is the enormous size of the classes. The new student coming from a small rural high school is bewildered when he walks into a large lecture section. He discovers that he is assigned a number in the seating arrangement in the class room and that his name is seldom mentioned in class.

Before long he begins to be aware of another difference, the lack of the close parental and school supervision he had in high school. This may be a snare in which he becomes entrapped before he realizes it. He has much more time at his disposal between and after class hours. He has the difficult problem of how to distribute his time between preparation for classes and outside activities. If he is doing part-time work, the problem becomes even more complicated. If a student is a slow reader, he may complain about having insufficient time to handle the long assignments.

As the adviser works with the advisee, he presents the pros and cons involved in each situation in such a manner that the advisee must make his own decisions while trying to make adjustments to the conditions of college life. At first this is a painful ordeal. Finding that he not only must make his own decisions but also assume the responsibility for those decisions once they are made is a part of the entire struggle of adjusting to the college program, a part of the educational process. The more decisions that the adviser will make for an advisee, the more he becomes a prop or a crutch for the student and the less responsibility the student will assume.

Teaching the student to make his own decisions and to assume responsibility for those decisions is another objective in the process of successful advising and counseling.

In a recent conversation, Dr. J. C. Holmes, Dean of Men at the University of Redlands, Redlands, Calif., used an illustration which aptly describes the goal of counseling. He stated that in the counseling process he thought there was conscious effort on the part of the adviser and advisee which is somewhat comparable to that of bringing the two triangles in a range finder on a camera into focus. One of the triangles represents reality and the other the concept of self. In this discussion the triangle designated as reality represents the conditions of the college environment. The triangle designated as concept of self represents the advisee's understanding of himself, his environment, his aims, and his abilities. The advisee, with the help of the adviser, is attempting to bring these two triangles into focus. When this has been accomplished, the advising and counseling service has rendered an outstanding contribution to education. The student who has learned to weigh the facts, make decisions, and take the responsibility for those decisions, should be an asset as a citizen to any community where he later chooses to live.

Notes

SEED PRODUCTION AND MOISTURE CONTENT OF LADINO CLOVER, *Trifolium repens* L., TREATED WITH ENDOTHAL[1]

INTEREST in Ladino clover seed production in Wisconsin is sustained because of the importance of Ladino clover in recommended forage crop mixtures. Harvesting Ladino clover seed under Wisconsin conditions, however, presents a difficult problem.

Under the conventional method, the windrows often remain in the field for 10 days to 2 weeks for drying. During that period, adverse weather may cause considerable loss in seed yield. This note presents results of an experiment conducted at Madison, Wis., *(1)* to determine the effect of time of harvest on seed production, and *(2)* to test the use of a desiccating chemical to facilitate harvesting.

The Ladino clover used in this study was established in 1951 on a Miami silt loam soil of rather uniform topography. The clover had been clipped back in the spring to a uniform height of 3 to 4 inches. Experimental plots were 30 by 50 feet in size and a randomized complete block design was used.

Endothal[2] was applied at 40 pounds pressure to different plots at concentrations ranging from 2 through 6 quarts per acre on July 29 and on August 25, 1952. One application of 4 quarts per acre was also applied on Aug. 11.

Samples for seed yield and moisture determination were taken at 1-, 3- and 5-day intervals following each treatment. The samples were hand clipped from square yard areas, and four samples were taken at random from each treatment at each interval. These were dried, threshed by a scarifier, cleaned on a Clipper fanning mill, and further cleaned on an electrical air blower machine. The yield of cleaned seed was calculated in pounds per acre. The moisture content of the treated plants was calculated as the percent of the untreated.

The average yields of Ladino clover seed in pounds per acre at 1-, 3-, and 5-day intervals of harvesting after spraying on July 29 and Aug. 25 for sprayed versus unsprayed plots are shown in table 1.

In all comparisons, the average yield of seed for those plots harvested after the late date of spraying was more than that for plots harvested following the earlier date. This difference was highly significant.

The number of flowers formed was considerably greater during the warm, dry, sunny month of August than during July. Soil moisture was more abundant in July and vegetative growth predominated over flower formation. The

[1] Contribution from Departments of Agronomy and Entomology, University of Wisconsin. Published with approval of the Director, Wisconsin Agr. Exp. Sta. Received May 5, 1955.

[2] One gallon of the formulation used contained 2/3 pound of technical disodium 3, 6 endoxohexahydrophthalate, 3 1/3 pounds of ammonium sulfate, 1 ounce of "activator" and water.

warm, dry period in August was also more conducive to pollination activity of bees. This increased activity resulted in a larger amount of seed set. Seed production was, therefore, larger in August than July. Dessureaux[3] stated that weekly variations do occur in seed setting and apparently are a result of the complex interaction of several climatic factors which are favorable to bee activity.

There were no significant differences in the yield of seed among plots treated with 2 through 6 quarts of endothal per acre and untreated plots. However, the yield of seed from untreated plots, over all intervals of harvesting and both dates of spraying, was higher than the yield from plots treated with endothal. This seemed to indicate that the endothal stopped or slowed down physiological processes associated with the maturing of seed. Possibly it prevented many seeds from developing or stopped the maturity of others. The small shrivelled seed resulting from this treatment were also lost in threshing and cleaning. The maturing of seed proceeded unhindered in the untreated plots, thereby giving a higher yield of seed. From these data, it would seem highly desirable that Ladino clover have its maximum set of seed formed at the time it is treated with endothal, or seed production may be reduced.

Significant differences were found between intervals of harvesting at each of the two treatment dates. A significant difference existed between the 1- and 3-day interval of harvesting and also between the 3- and 5-day intervals. However, differences were not significant between the 1- and 5-day intervals when measured by Duncan's multiple range test.[4] The highest yields were obtained when harvesting occurred at 3 days following treatment, and the lowest at 5 days. It is not clear why the differences between intervals of sampling were so large.

The analysis of variance showed a significant difference for the interaction of intervals of harvesting × dates of spraying. A further breakdown of this interaction showed that the interaction was not significant for the early date of spraying but was for the late. Since the formation of seed was greater at the late date of spraying, the interval of harvesting for obtaining the largest yield of seed was more critical at a period when more seed was being formed than at a period when fewer seed was being formed.

Average yields of seed in pounds per acre for unsprayed plots and plots sprayed with 4 quarts of endothal per acre on July 29, Aug. 11, and Aug. 25 are given in table 2.

For both sprayed and unsprayed plots and three intervals of harvesting, those plots harvested late yielded more seed on the average than those harvested at the early and middle dates of spraying. However, these differences were not significant. The data of table 2 show that the average yield of seed harvested at the middle date of spraying was never as great as that harvested at the late date. In only one case were seed yields from plots harvested at the early date of spraying as large as those harvested late, namely, at the 5-day interval of harvesting for the unsprayed plots.

The yield of seed following the middle date of spraying was less than the yield following the early date. This reduced seed yield appeared to be associated with rainy weather which limited flower formation and bee activity.

[3] Dessureaux, L. Variation in the seed setting ability of Ladino white clover. Sci. Agr. 30:509–517. 1950.

[4] Duncan, D. B. Multiple range and multiple F tests. Biometrics 2:1–42. 1955.

Table 1.—Average yield of Ladino clover seed in pounds per acre for sprayed and unsprayed plots when sprayed on July 29 and Aug. 25. Average of four samples. Madison, 1952.

Treatment	Harvesting interval after treatment (days)			Average
	1	3	5	
Unsprayed E*	166	154	177	166**
L	190	216	106	171
Average	178	185	142	168N.S.†
Sprayed E	99	123	117	113**
L	154	170	133	152
Average	127	146	125	132
Average	152	166	134	150

Significance among intervals of harvest using Duncan's 5% multiple range test.

	Harvesting interval (days)		
	5	1	3
Ave. yield of seed	134	152	166

* E = Early date of spraying; L = Late date of spraying.
** Significant at 1% level in comparison of early and late dates.
† Non-significant in comparison of sprayed and unsprayed plots.

Table 2.—Average yield of Ladino clover seed in pounds per acre for unsprayed plots and plots sprayed with 4 quarts of endothal per acre on July 29, Aug. 11, and Aug. 25. Average of four samples. Madison, 1952.

Treatment	Harvesting interval after treatment (days)			Average
	1	3	5	
Check E*	166	154	177	166
M	126	119	82	109
L	190	216	106	171
Average	161	163	122	149†
4 qts. E	88	125	101	104
M	127	126	110	121
L	143	178	135	152
Average	119	143	115	126
Average E	127	139	139	135‡
M	126	123	97	115
L	167	197	121	162
Average	140§	153	119	137

* E = Early date of spraying; M = Medium date of spraying; L = Late date of spraying.
† Non-significant at 5% level in comparison of sprayed and unsprayed plots.
‡ Non-significant at 5% level in comparison of early, medium and late dates.
§ Non-significant at 5% level in comparison of 1-, 3-, and 5-day intervals when using Duncan's multiple range test.

A total of 7.6 inches of rain fell during July, much of it during the middle part of the month. Only 4.7 inches of rainfall were recorded for August.

A significant interaction was obtained for treatments × dates of spraying. The difference occurred at the early date of spraying where the unsprayed plots yielded significantly more seed than the sprayed. Apparently, the treatment with

Table 3.—Average percentages of moisture for Ladino clover forage at 1, 3, and 5 days after treatment with different concentrations of endothal sprayed on Aug. 25. Average of four samples. Madison, 1952.

Concentration	Harvesting interval after treatment (days)			Average
	1	3	5	
Check	100.*	100.	100.	100.
2 qts.	97.1	84.2	82.4	87.9
3 qts.	95.6	83.4	79.7	86.2
4 qts.	95.1	81.9	81.2	86.1
5 qts.	94.5	81.4	77.0	84.3
6 qts.	93.4	78.9	74.9	82.4
Ave.	96.0	85.0	82.5	87.8

* Check adjusted to 100.

endothal at the early date was made at a critical time of rapid seed formation; thus the yield of seed was decidedly lowered within a five-day period.

The average yield of seed was greater for the untreated plots than for the treated, and the largest yield of seed was obtained at a harvesting interval of 3 days following treatment. These data were consistent with those given for 2 dates of spraying with 2 to 6 quarts of endothal.

Table 3 shows that a loss of moisture occurred in all treated plots. The greatest loss occurred from the first to the third day after treatment. The loss between the third and fifth days was relatively less. Increasing concentrations of endothal per acre caused a progressive decrease in moisture except for the 4-quart rate at the 5-day interval of sampling.

Data for the spraying made on July 29 are not shown, but differences were of the same order except that a greater reduction in moisture occurred. This was probably due to differences in weather conditions at the two dates of spraying and also to the greater succulence of the Ladino clover at the earlier date.

While these results are based on only 1 year's data and are not conclusive, they do seem to indicate that later harvest dates may give higher seed yields, and that treatment with endothal may increase the speed and ease of harvesting by lowering the moisture content.—M. A. MASSENGALE, *and* J. T. MEDLER, *Research Assistant and Associate Professor, Departments of Agronomy and Entomology, respectively, University of Wisconsin.*

THE EFFECT OF THE ADDITION OF VAMA TO SOIL UPON UPTAKE OF PHOSPHORUS AND THE UTILIZATION OF PHOSPHORUS APPLIED IN FERTILIZER BY THE OAT PLANT[1]

THE Maine Agricultural Experiment Station began studies in 1952 to determine the effect of the chemical soil conditioner VAMA (a modified vinyl acetate-maleic acid) upon the availability of plant nutrients in a poorly drained phase of Scantic silty clay. Tagged superphosphate, potassium chloride, ammonium nitrate, and VAMA were added to weighed amounts of air-dry soil. The soil was moistened, thoroughly mixed, and placed in replicated pots with the several treatments: no VAMA, VAMA added and mixed with soil before plant nutrients were added, and VAMA added and mixed with the soil after plant nutrients were added.

Oats were grown during the years 1952 to 1954, and in 1953 bush beans were included. Soil from the same source was used for the whole series and showed a low analysis, or 32 to 34 pounds per acre phosphorus. No attempt was made to evaluate soil structure except by visual observations.

In 1952 and 1953, several rates of plant nutrients and VAMA were used; namely, 80, 120, and 160 pounds P_2O_5 and 1,000 and 2,000 pounds of VAMA. In 1954, only the higher rates were used, 160 pounds P_2O_5, 100 pounds N, 310 pounds K_2O, and 2,000 pounds VAMA per acre, since in previous years trends were the same for rates used.

To determine the availability of the plant nutrients, the crop was harvested at maturity, and the plants analyzed chemically to determine the amounts of nutrients taken up by the plant. Radioactive counts were made of the phosphorus to determine the percentage uptake from the fertilizer.

Results shown in table 1 indicate that the oat plant can more efficiently use the fertilizer phosphorus when VAMA is not present in the soil. Also, the plant is able to assimilate more phosphorus when VAMA is not present in the soil. In the 2 years, 1953 and 1954, when VAMA was added to the soil with no fertilizer phosphorus added, this treatment showed a significant decrease in plant phosphorus uptake when VAMA was added than when no VAMA was used.

In the 3 years' results when 160 pounds per acre of phosphorus was used with and without VAMA, a significantly lower uptake of phosphorus was shown when VAMA was used as opposed to when no VAMA was used.

There was also some evidence during trials that time of application of VAMA was important, and in the first years of trials, 1952, there was a significantly higher percentage of fertilizer phosphorus used by the plant when the VAMA was applied to the soil first and the phos-

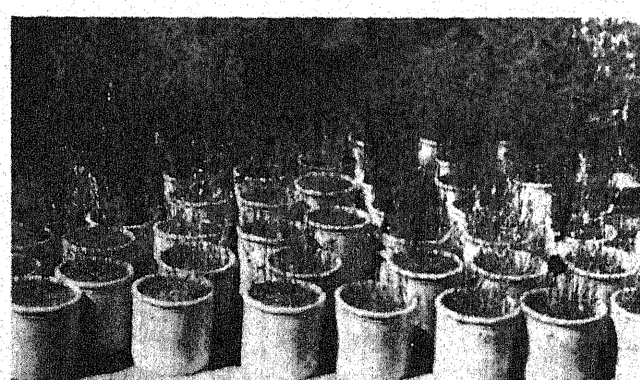

FIG. 1.—Pots in the foreground had no VAMA added. Pots to the right and left, as well as in the background, had VAMA added. It can be observed that those without VAMA have yellowed and matured, while the VAMA-treated pots are still green and show active growth. However, dry weight of VAMA-treated pots averaged lower than untreated pots.

[1] Received April 20, 1955.

Table 1.—Percent phosphorus content of oat plants and percent phosphorus from the fertilizer as affected by addition of VAMA to the soil before and after the addition of phosphorus fertilizer.

Treatment	Percent phosphorus in plant				Percent phosphorus from the fertilizer in the plant			
	1952	1953	1954	Ave. for 3 years	1952	1953	1954	Ave. for 3 years
0 lb. P_2O_5—No VAMA	0.062	0.221	0.188	0.157	——	——	——	——
0 lb. P_2O_5+2000 lb. VAMA	——	0.211	0.103	——	——	——	——	——
160 lb. P_2O_5+No VAMA	0.086	0.350	0.267	0.217	3.44	2.59	6.02	4.01
160 lb. P_2O_5+2000 lb. VAMA added before P_2O_5	0.080	0.267	0.191	0.179	3.22	2.68	3.69	3.20
160 lb. P_2O_5+2000 lb. VAMA added after P_2O_5	0.090	0.257	0.191	0.179	2.31	3.19	4.98	3.49
L.S.D. 0.05	0.014	0.046	0.036	0.025	0.71	0.23	2.09	——

phorus later, as opposed to the reverse treatment. However, the 1953 and 1954 results did not substantiate the data of 1952 in this respect.

Bush beans were used in addition to oats as an indicator plant in 1953, and results were very similar to those with oats.

From this study it would appear that the use of soil conditioning compounds tend to inhibit the uptake of soil and fertilizer phosphorus by the oat plant, even though soil physical structure is improved.

It was observed that soil granulation was much improved when VAMA was used. Soil without VAMA added puddled badly and baked on drying while with the VAMA it remained porous and in good physical condition.—PAUL N. CARPENTER, *Assistant Agronomist, and* R. A. STRUCHTEMEYER, *Agronomist, Main Agr. Exp. Sta.*

Registration of Barley Varieties, XIII[1]

I. J. Johnson[2]

TWENTY-FOUR varieties of barley have been registered prior to this report, the last report appearing in July 1953.[3] One variety, Cordova, was approved for registration in 1955.

CORDOVA BARLEY (Reg. No. 25)

Cordova (C.I.7576,[4] Tex. 8–43–311) was developed at the Denton Substation of the Texas Agricultural Experimental Station in cooperation with the U. S. Department of Agriculture from a cross between Wintex and Texan, two locally adapted varieties. The cross was made by Dr. G. A. Wiebe and the F_1 plants were grown at Sacaton, Ariz. Seed from these plants were sent to Denton, Tex., in 1939 and the selection 8–43–311, made by Dr. I. M. Atkins was named Cordova. A more complete description of this variety by Atkins has been published.[5]

Cordova is 6-row intermediate winter-type barley with smooth awns and a moderate plant height. It is sufficiently cold-resistant for most seasons in all except the High Plains area of Texas. The variety produces abundant fall and winter forage for livestock, tillers well, has plump grain, and has the capacity for very high yields under favorable conditions. Although Cordova is highly susceptible to leaf rust, stem rust, stripe and net blotch, it is resistant to the prevalent races of mildew in the area.

Foundation seed of Cordova was released to certified growers in the fall of 1952, and acreage expanded rapidly as a result of favorable seasons. It was grown on an estimated 30,000 acres in 1954.

Yields of Cordova in comparison was six other commercial varieties are given in table 1.

[1] Registered under a cooperative agreement between Field Crops Research Branch, A.R.S., U.S.D.A., and the American Society of Agronomy. Received Sept. 17, 1955.

[2] Professor in Charge of Farm Crops, Agronomy Department, Iowa State College, Ames, Iowa. Member of the 1955 Committee on Varietal Standardization and Registration charged with the registration of barley varieties.

[3] Johnson, I. J. Registration of Barley Varieties. Agron. Jour. 45:320–322. 1953.

[4] Accession number, Section of Cereal Crops and Diseases, U.S.D.A.

[5] Atkins, I. M. Cordova Barley. Texas Agr. Exp. Sta. Bul. 760. 1953.

Table 1.—Average yields of Cordova and seven commercial varieties of barley grown at several Texas locations, 1947–52.*

Location	Number years tested	Variety						
		Yields of grain, bushels per acre						
		Cordova	Texan	Wintex	Tenkow	Ward	Reno	Tennessee Winter
Fall-sown at:								
Amarillo	2	39.9	33.2	32.7	31.9	25.5	22.7	26.1
Chillicothe	5	41.3	38.0	29.9	35.6	35.0	29.1	29.5
Iowa Park	5	47.1	44.8	45.4	49.0	49.2	47.6	42.6
Stephenville	4	44.7	34.6	34.8	33.5	29.8	29.0	27.2
Denton	6	36.2	32.3	27.2	30.1	27.5	25.5	24.9
Greenville	4	35.1	32.7	33.6	38.1	29.6	27.6	28.0
Temple	3	38.8	34.6	—	—	—	—	21.1
Comfort	3	40.5	37.3	—	—	—	—	—
Average†		40.7	35.9	33.9	36.5	32.8	30.3	29.7
Spring-sown at:								
Amarillo	1	43.2	35.2	42.3	—	—	—	—

† Average of six locations, data from Temple and Comfort omitted. The least significant difference between two varieties at the 0.05% level is 3.3 bushels.

Registration of Varieties and Strains of Bromegrass (*Bromus* Spp), II[1]

M. A. Hein[2]

THIS is the second report on the registration of varieties and strains of bromegrass (*Bromus* spp.) according to the revised classification[3] of forage crops for registration purposes by Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, and the American Society of Agronomy. The previous report was published in 1951.[4]

HOMESTEADER BROMEGRASS (Reg. No. 3)

Homesteader, a variety of smooth bromegrass (*Bromus inermis* Leyss.), is a composite of five selected and tested strains of bromegrass from the Department of Agronomy, South Dakota Agricultural Experiment Station. These strains originated from farms on which the original plantings were made 40 or 50 years ago.

From the original 16 strains investigated, 5 strains were found to be superior on the basis of forage yield, seed production, palatability, and adaptability to the conditions of South Dakota. Homesteader is an intermediate type between the northern and southern bromegrass strains. It has been approved for the distribution, and registration was requested by the Department of Agronomy of the South Dakota Agricultural Experiment Station. Certified seed is being produced under the South Dakota Crop Improvement Association. Yield data comparing Homesteader with varieties Lincoln, and Canadian Commercial are given in table 1.

Foundation seed of Homesteader bromegrass is maintained by the South Dakota Agricultural Experimental Station. Ample supplies of certified seed are now available for the farmers in South Dakota. Additional information on Homesteader has been published.[5]

LANCASTER SMOOTH BROMEGRASS (Reg. No. 4)

Lancaster is a synthetic variety of smooth bromegrass (*Bromus inermis* Leyss.) developed cooperatively at the Nebraska Agricultural Experiment Station, Lincoln, Nebr., by the Department of Agronomy and the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture. It was produced in 1943 by the field hybridization of clones from five unrelated sources. The selection of the clones was based on previous evaluation of their sibbed and open-pollinated progenies, the studies beginning with selections from farmers' old fields in 1937. Lancaster showed immediate promise among several experimental synthetics in early comparative tests. On fertile soils it is a leafy, vigorous strain with fine stems and somewhat drooping panicles. This variety is comparatively free of diseases in its region of adaptation.

Results of two tests at Lincoln, Nebr., comparing Lancaster bromegrass wth other varieties in forage and seed yields in 4 years are presented in table 2. It is the leading variety in forage and seed yields and has been outstanding in its seed yield performance in these Nebraska tests. It has been tested widely in the North Central States where it is among the more promising varieties.

Seed of advanced generation first known as Nebraska 44 has been distributed for broader testing each year since 1947. The first farmer-produced seed crop of Lancaster bromegrass was certified by the Nebraska Crop Improvement Association in 1951. A foundation seed field is maintained by the Nebraska Station.

LINCOLN SMOOTH BROMEGRASS (Reg. No. 5)

Lincoln is a variety of smooth bromegrass (*Bromus inermis* Leyss.) developed at the Nebraska Agricultural Experiment Station, Lincoln, Nebr., by the Department of Agronomy and the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture. Following the thirties, there was an increased interest in bromegrass as a grass which would withstand recurrent droughts. Farmer success with seed of local type led to a series of tests of farmers' strains obtained from fields in Kansas, Nebraska, the Dakotas, and Canada.

The best performing Nebraska fields of similar type were traced to old plantings, some of which were made from the distribution of seed prior to 1898. The later distribution of seed from the tested fields was named Lincoln and was first certified by the Nebraska Crop Improvement Association in 1943. The variety has been widely tested and grown in the Northern States and selections from it are being used widely in the production of newer varieties. Lincoln is a variety characterized by ease of establishment of seedlings, good yields of forage and seed, and comparative freedom from diseases in its region of adaptation.

Table 3 summarizes part of the data from early tests which show the superiority of the Southern strains, Lincoln and Achenbach, in both forage and seed yields as compared with Northern strains.

A foundation seed field is maintained by the Foundation Seed Division of the Nebraska Agricultural Experiment Station. Additional information on Lincoln bromegrass has been published.[6]

Table 1.—Forage yields of Homsteader bromegrass compared to Lincoln and Canadian Commercial at Brookings, S. Dak.

Varieties	Yields in tons of air-dry hay per acre					
	1946	1947	1948	1949	1950	Average
Homesteader	2.78	1.65	0.94	0.37	0.70	1.29
Lincoln	2.66	1.70	.87	.49	.55	1.25
Canadian Commercial	2.64	1.30	.83	.41	.60	1.14

[1] Registered under a cooperative agreement between Field Crops Research Branch, A.R.S., U.S.D.A., and the American Society of Agronomy. Received Sept. 17, 1955.

[2] Principal Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A. Member of the 1955 Committee on Varietal Standardization and Registration charged with the registration of grass varieties.

[3] Report of the Committee on Varietal Standardization and Registration. Agron. Jour. 43:50. 1951.

[4] Myers, W. M. Registration of Varieties and Strains of Bromegrass (*Bromus* spp.) Agron. Jour. 43:237. 1951.

[5] South Dakota Farm and Home Research. Vol. II No. 2, 1951.

[6] Nebraska Crop Improvement, 34th Annual Report, 1943, by L. C. Newell and F. D. Keim; and Field Performance of Bromegrass Strains from Different Regional Seed Sources. Jour. Amer. Soc. of Agron. 35:420–434, 1943.

Table 2.—Forage and seed yields of bromegrass varieties at Lincoln, Nebr., 1947–52.

Variety	Forage yield, tons/acre					Seed yields, lbs./acre				
	Five reps.		Three reps.		Ave.	Five reps.		Three reps.		Ave.
	1947	1948	1951	1952		1947	1948	1951	1952	
Lancaster	4.29	2.18	2.24	3.01	2.93	590	469	474	535	517
Lincoln (2 series of plots)	3.70	1.80	1.80	3.13	2.60	494	378	446	405	431
Achenbach	——	——	2.02	3.02	(2.52)	——	——	348	448	(398)
Canadian	2.94	1.21	1.56	2.56	2.07	411	307	232	372	330
	Comparisons of means with mean of Lincoln (2 series of plots)									
L.S.D. at P=0.05	0.33	0.19	0.35	0.28	——	79	89	129	128	——
	Other comparisons of means									
L.S.D. at P=0.05	0.38	0.22	0.40	0.32	——	91	103	148	147	——

Table 3.—Forage and seed yields of bromegrass strains at Lincoln, Nebr., 1941–42.*

Source	Forage Tons/acre (12%) Six replications		Seed Lb./acre Four replications	
	1941	1942	1941	1942
Canadian (3 commercial strains)	1.06	0.82	147	143
North Dakota (3 commercial strains)	1.33	1.00	187	159
Nebraska Northern (3 farmer's strains)	1.53	1.13	231	177
Nebraska Lincoln (3 related fields)‡	2.21	1.27	383	161
Kansas Achenbach (3 related fields)	2.23	1.31	2.39	78
L.S.D. between means of 3 strains				
at P=0.05	0.29	0.13	107	46
at P=0.01	0.38	0.17	143	61

* Data from Newell, L. C., and Keim, F. D. Field performance of bromegrass strains from different regional seed sources. Jour. Amer. Soc. Agron. 35: 420–434. 1943.

† Strains 4, 8, and 24 in the original test were from fields later certified as Lincoln.

LYON SMOOTH BROMEGRASS (Reg. No. 6)

Lyon smooth bromegrass, a variety of *Bomus inermis* Leyss., was developed cooperatively at the Nebraska Agricultural Experiment Station by the Department of Agronomy and the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture. This variety was initially a mass selection from one farmer's field of Lincoln bromegrass, produced by two generations of selection among nursery-spaced plants. The resulting strain known as B9 was tested in early uniform trials in many states. At Lincoln, Nebr., in a subsequent nursery, progenies of the parental clones of B9 were allowed to outcross to a wide range of bromegrass selections. Seed harvested from the B9 source was of exceptional quality and it was planted for increase. It proved more vegetatively aggressive than the original B9 and was retained. Advanced generation seed of this variety, known as Nebraska 36 and later as Lyon, has been distributed for extensive testing since 1947. Lyon produces large yields and has an excellent quality of seed. It maintains the qualities of seedling vigor and ease of establishment of Lincoln bromegrass but is more uniform as to plant type. Preliminary tests indicate it is best adapted in the Western part of the region where bromegrass is grown.

Comparative yields of Lyon in relation to Lancaster and check varieties at Lincoln, Nebr., during a 4-year period are presented in table 4. Certified seed of this variety was first produced on farms in 1951. Foundation seed is maintained by the Nebraska Station.

Table 4.—Forage and seed yields of bromegrass varieties at Lincoln, Nebr., 1947–52.

Variety	Forage yields, tons/acre					Seed yields, lbs./acre				
	Five reps.		Three reps.		Ave.	Five reps.		Three reps.		Ave.
	1947	1948	1951	1952		1947	1948	1951	1952	
Lyon	4.04	2.11	1.99	3.15	2.82	536	566	405	502	502
Lincoln (2 series of plots)	3.70	1.80	1.80	3.13	2.60	494	378	446	405	431
Achenbach	——	——	2.02	3.02	(2.52)	——	——	348	448	(398)
Canadian	2.94	1.21	1.56	2.56	2.07	411	307	232	372	330
	Comparisons of means with mean of Lincoln (2 series of plots)									
L.S.D. at P=0.05	0.33	0.19	0.35	0.28	——	79	89	129	128	——
	Other comparisons of means									
L.S.D. at P=0.05	0.38	0.22	0.40	0.32	——	91	103	148	147	——

Registration of Oat Varieties, XX[1]

H. C. Murphy[2]

THE nineteenth consecutive report on the registration of oat varieties was published in November 1954 (12). Five varieties, Alamo, Cimarron, Seminole, Floriland and Victorgrain 48–93, were approved for registration in 1955.

ALAMO (Reg. No. 133)

Alamo (C.I. 5371,[3] Sel. 73–44–90) originated at the Texas Agricultural Experiment Substation No. 6, Denton, Tex., as a selection from (Victoria × Hajira–Banner, C.I. 4019) × (Fulghum × Victoria, C.I. 3528). C.I. 4019 was developed by J. N. Welsh, Dominion Cereal Breeding Laboratory, Winnipeg, Manitoba. C.I. 3528, a sister strain of the variety Fultex (13), was developed cooperatively by the U. S. Department of Agriculture and the Texas Agricultural Experiment Station. The cross from which Alamo was selected was made at Ames, Iowa, by H. C. Murphy, during the winter of 1940–41. The F_1 plant was grown by Harland Stevens at Aberdeen, Idaho, in the summer of 1941. Seed for the F_2 generation was sent to I. M. Atkins in October 1941 for growing at Denton in 1942. The selection and testing for disease reaction, yield, and other characteristics were made by I. M. Atkins. Sel. No. 73–44–90 was first selected in 1944 and then reselected in 1946. George Rivers of Texas A. & M. College assisted in the tests to determine the adaptation in Texas.

Alamo is an attractive, early maturing variety, averaging 7 days earlier than New Nortex. It is of medium height with standing ability for direct combine harvesting. The kernels are red, short, and plump with practically no awns, and are of high test weight and excellent quality. In 30 fall-sown comparisons, Alamo averaged 2 pounds higher in test weight than Mustang and 4 pounds higher than New Nortex. The superiority of Alamo in spring-sown tests was even greater.

The new variety is not very resistant to cold, which will limit its use for fall seeding to southern Texas. It is especially well adapted for spring seeding throughout the northern half of the state including the High Plain or Panhandle area. Because of susceptibility to *Helminthosporium victoriae* Meehan and Murphy, Alamo should be grown in rotation with other crops and the seed should be treated with Ceresan M or some other seed disinfectant.

Alamo has been outstanding for yield from both fall and spring sowing in Texas, as indicated in table 1. Owing to its early maturity and upright type of growth, it has been found especially desirable as a companion crop for establishing sweetclover from spring seeding in North Texas.

Alamo is the first variety named and distributed in the United States with combined high resistance to the races of crown rust and stem rust now prevalent. It is resistant to all races of stem rust except 7A, and to all races of crown rust except those attacking Victoria. Its greatest

[1] Registered under a cooperative agreement between the Field Crops Research Branch, A.R.S., U.S.D.A. and the American Society of Agronomy. Received Sept. 17, 1955.

[2] Principal Pathologist, Field Crops Research Branch, A.R.S., U.S.D.A. Member of 1955 Committee on Varietal Standardization and Registration charged with the registration of oat varieties.

[3] C.I. refers to accession number of the Cereal Crops Section.

Table 1.—Average yields of Alamo and four commercial varieties of fall-sown oats at locations in Southern Texas, 1947–52, and from spring-seeding at stations in the northern part of the state, 1947–53.

Locations	Number years tested	Yield of grain, bushels per acre					
		Alamo	Fultex	Frazier	Mustang	New Nortex	L.S.D.
		Fall sown					
Southern stations							
Winter Haven	1	51.6	36.3	31.2	42.2	22.8	10.6
Beeville	1	31.3	30.1	22.8	33.2	23.1	4.9
Prairie View	1	41.5	37.2	28.3	42.0	34.1	7.5
College Station	4	65.2	42.6	33.6	59.4	47.0	9.3
Brazos River Lab.	1	26.1	21.0	25.2	21.1	28.3	3.1
Lockhart	1	22.3	23.7	14.6	25.7	20.6	6.2
Comfort	3	56.8	49.0	41.2	55.3	45.5	5.8
Weighted average		50.3	38.8	31.7	47.3	37.8	
		Spring sown					
Northern stations							
Amarillo	2	35.9	31.4	35.2	35.0	29.8	7.7
Chillicothe	2	29.5	29.0	26.5	26.6	11.5	——
Iowa Park	2	60.3	59.4	54.3	57.2	38.4	5.9
Denton	7	65.3	57.5	53.6	62.4	53.0	4.1
Greenville	2	78.7	67.8	61.7	57.0	45.4	11.7
Comfort	3	34.0	25.1	39.2	27.9	25.3	6.4
McGregor	1	63.6	60.3	44.8	62.3	45.1	5.4
Temple	1	49.3	40.7	40.2	41.9	34.0	9.4
Weighted average		54.0	46.9	46.1	48.2	38.4	

weakness, from the standpoint of disease resistance, is susceptibility to *H. victoriae.*

Foundation seed of Alamo was released to certified seed growers in Texas in the fall of 1953. It is a product of cooperative oat breeding investigations between the Texas, Iowa, and Idaho Agricultural Experiment Stations, and the U. S. Department of Agriculture.

The application for the registration of Alamo was submitted by I. M. Atkins, who supplied the information on its description and performance. The origin, history, description, and performance in Texas of Alamo has been published (2). Additional data on its performance in uniform regional nurseries have been reported (4, 5, 6, 7, 8, 9).

CIMARRON (Reg. No. 134)

Cimarron (C.I. 5106, Sel. 472606) originated at the Oklahoma Agricultural Experiment Station, Stillwater, Okla., as a mass selection of early maturing panicles from Woodward Winter Oat Composite (C.I. 3527) made by A. M. Schlehuber in the spring of 1946. C.I. 3527 originated as a "bulk" of all the surviving plants of 30 oat varieties grown in U.S.D.A. uniform oat winter hardiness nursery at the Southern Great Plains Field Station, Woodward, Okla., during the severe winter of 1934–35. The total survival was estimated at only 2 to 3%. This bulk was grown as a composite from 1936 through 1946. It was a mixture of many types, including tall and short plants, early and late maturity, red and yellow grain, etc. No variety grown in the 1934–35 nursery, or any year since, is similar to Cimarron. Therefore, its parentage and exact origin are unknown.

The early maturing panicles selected from C.I. 3527 in the spring of 1946 were examined before threshing and found alike for panicle and seed type. The seed was then bulked and used to plant seven 4-foot rows in the fall of 1946. The survival was 80%, with a minimum temperature of –17° F. in February 1947, and the total yield was 1,300 g. This bulked lot, then designated "Woodward Composite Oat, Stillwater Selection 472606" was grown in yield nurseries at various locations in Oklahoma starting in 1947–48. It was further purified by growing and roguing 4,095 panicle hills in 1950–51. The Oklahoma Seed Stocks, Inc., distributed approximately 3,500 bushels of foundation seed of Cimarron, C.I. 5106, to Oklahoma certified seed growers in the fall of 1954.

Cimarron is an extremely early maturing, short-strawed, winter hardy type variety, with semi-erect to erect wide green leaves, whic hare somewhat blunt at the apex. The kernels are small to medium in size, with test weight equal to Wintok, a heavy oat. They range in color from almost white, through yellow, to light gray. The gray color and gray striping of the lemma and palea is influenced by environmental conditions. The variety is classified as *Avena sativa.*

The unique ability of Cimarron, a winter-hardy oat, to perform well from both fall- and spring-seeding has earned it the title of a "Two-Way" or "Dual Purpose" variety. The performance of Cimarron when fall-sown in comparison with the leading winter varieties Tennex, Forkedeer, and Wintok, is presented in table 2. Its average yield for 18 station years was 17% above Wintok and 8% above Tennex and Forkedeer. When spring-sown, only Andrew, the highest yielding spring-sown variety in Oklahoma, exceeded Cimarron by a nonsignificant amount, whereas Cimarron outyielded Kanota, the next highest yielding spring variety, by 4.4 bushels per acre (table 3). Cimarron has been outstanding for both fall and spring forage (grazing) value, in comparison with Lee and Wintok. It is equal to Forkedeer for winter hardiness but somewhat less hardy than the outstanding Wintok and Tennex. Cimarron is susceptible to crown and stem rust, and to a leaf spot disease tentatively identified as *Cladosporium* spp.

Cimarron (C.I. 5106) is a product of the cooperative oat breeding investigations between the Oklahoma Agricultural Experiment Station and the U. S. Department of Agriculture, and was developed by A. M. Schlehuber. Application for registration was submitted, and information on the origin, history, and performance was supplied by him. A report on the merits of Cimarron has been published (1). Additional information on its performance in regional tests had been published (4, 5, 6, 7, 8, 9).

SEMINOLE (Reg. No. 135)

Seminole (C.I. 5924, Sel. 6514) originated as a selection from the cross Appler × (Clinton[2] × Santa Fe). The

Table 3.—Yield of Cimarron, Andrew, Kanota, Neosho, and Red Rustproof from spring seeding at Stillwater, Okla., in 1951 to 1954.

Variety	Bushels per acre				
	1951	1952	1953	1954	Ave.
Andrew	38.3	53.3	16.8	44.2	38.2
Cimarron	38.9	44.7	17.9	47.9	37.4
Kanota	33.5	40.0	20.7	37.7	33.0
Neosho	31.2	48.3	13.9	29.1	30.6
Red Rustproof	28.5	41.5	2.6	38.5	27.8

Table 2.—Yield in bushels per acre of Cimarron, Tennex, Forkedeer, and Wintok fall-sown at four locations in Oklahoma for all or a part of 1948–54.

Variety	C.I.	Stillwater 1950–1954		Woodward 1948–1954*		Cherokee 1949–1954†		Goodwell 1949–1954*		Percent of Wintok 18 station-years
		Ave.	Rank	Ave.	Rank	Ave.	Rank	Ave.	Rank	
Cimarron	5106	38.4	3	46.2	1	43.6	3	22.7	1	117
Tennex	3169	41.5	1	39.5	2	44.0	1	14.5	4	105
Forkedeer	3170	41.5	1	38.3	4	44.0	1	16.2	2	105
Wintok	3424	35.5	4	38.7	3	39.3	4	16.2	2	100

* Crop failures in 1950 and 1951.
† Crop failures in 1951 and 1953.

description and origin of Clinton, Appler, and Santa Fe have been published (14, 15). Clinton was first crossed to Santa Fe at the Iowa Agricultural Experiment Station, Ames, Iowa, by H. C. Murphy in 1945. The backcross to Clinton was made at Ames by D. D. Morey and H. C. Murphy in 1946. Several of the resulting plants were grown at the Idaho Agricultural Experiment Substation, Aberdeen, Idaho, in 1947, where F. A. Coffman crossed Appler with one of them. The F_1 plant of Appler × (Clinton^2 × Santa Fe) was grown in the greenhouse at Beltsville, Md., during the winter of 1947–48, and the F_2 plants grown at Aberdeen, Idaho, in 1947. Bulked seeds from the F_2 plants were sent to D. D. Morey, Georgia Agricultural Experiment Station, Athens, Ga., for F_3 planting in the fall of 1948. Seventy-three panicles selected from crown rust-resistant plants at Athens in the spring of 1949 were taken to the Agricultural Experiment Station, Gainesville, Fla., by D. D. Morey, for planting headrows the following fall. One of these F_4 headrows (No. 6514) was outstanding for resistance to diseases, earliness, and grain quality in 1949–50. The seed was sent to Aberdeen, Idaho, for increase during the summer of 1950. It was entered in Florida and regional tests in the fall of 1950. Appler × (Clinton^2 × Santa Fe), C.I. 5924, Sel. 6514, was named Seminole, and foundation seed was released by the Florida Station for sowing in the fall of 1953.

Seminole has an early, upright habit of growth. Under mild weather conditions it has a high forage yield potential. It is not winter-hardy, however, and can be severely injured by cold weather. It is an early maturing variety with short and relatively strong straw. Grain and forage yields have been good in the Coastal Plain area, where it is best adapted (table 4). The kernels are plump and of good quality under favorable growing conditions, and range from white through gray striped to gray in color. Along with Floriland and Sunland, Seminole is expected to occupy most of the Florida oat acreage now planted to Southland, which is now being damaged by culm rot and certain races of crown rust.

The crown rust resistance of Seminole, inherited from the Santa Fe parent, has been adequate under field conditions in the Coastal Plain area. It was immune to all 15 races of loose smut and 7 races of covered smut tested by C. S. Holton at Pullman, Wash., in 1954, and is resistant to *Helminthosporium victoriae*. Seminole is susceptible to stem rust.

Application for the registration of Seminole was submitted by D. D. Morey and F. A. Coffman. Other workers, in addition to those mentioned, who had a part in its development were W. H. Chapman and R. W. Earhart. Seminole is a product of cooperative oat breeding investigations between the Florida, Georgia, Idaho, and Iowa Agricultural Experiment Stations, and the U. S. Department of Agriculture.

Table 4.—Average yields of grain and forage for five oat varieties grown in Coastal Plain area 1951–1954.

	Grain yields (Bu. per acre)	Forage yields (Lbs. green wt. per acre)
Number of tests	23	5
Seminole	56	5,598
Floriland	53	5,336
Sunland	52	5,269
Southland	45	5,600
Red Rustproof	38	3,591

The origin, history, development and release of Seminole have been published (10). Additional information on its performance in uniform regional yield nurseries has been reported (6, 7, 8, 9).

FLORILAND (Reg. No. 136)

Floriland (C.I. 6588) originated at the North Florida Agricultural Experiment Station, Quincy, Fla., from the cross Florida 167 (C.I. 4320) × Landhafer (C.I. 3522) made by F. A. Coffman, U. S. Department of Agriculture, Beltsville, Md., in 1947. The Florida 167 (C.I. 4320) parent originated as a selection from a cross of Bond × Fulghum made at the Florida Agricultural Experiment Station in 1935 or 1936. The history of the Landhafer parent has been published (15). In the fall of 1948, seed from 14 F_2 plants were planted in headrows at Quincy, Fla., by W. H. Chapman. One of these F_3 rows was outstanding and seed from it was increased at the Idaho Agricultural Experiment Substation, Aberdeen, Idaho, during the summer of 1949. Data from 750 headrows grown at Quincy, Fla., during 1949–50 indicated the original selection was pure for resistance to crown rust but not for maturity. The crown rust resistance was so oustanding that 27 of the early maturing lines, with low leaf spot (*Helminthosporium avenae* Eidam.) readings, were bulked and increased at Aberdeen, Idaho, during the summer of 1950. The bulked seed of these lines gave rise to Floriland, which was released by the Florida Agricultural Experiment Station in the fall of 1952.

Table 5.—Average yield of Floriland, Southland and Red Rustproof No. 14 in Florida during 1951 to 1954.

Variety	Yield in bushels per acre				
	1951	1952	1953	1954	Ave.
Number of tests	4	11	10	10	35
Floriland	53.4	65.8	52.8	53.8	57.2
Southland	55.0	63.6	48.3	42.9	52.3
Red Rustproof No. 14	53.7	54.7	40.9	38.5	46.0

The outstanding characteristics of the new variety are high grain yield, excellent forage production, and high resistance to crown rust. The average yields of grain of Floriland, Southland, and Red Rustproof 14 in Florida yield tests during 1951 to 1954, are presented in table 5. The average reactions of these same varieties to Victoria blight, culm rot, leaf spot, stem rust, and crown rust for the same period are presented in table 6.

Floriland has been superior to Southland in grain production, and 10 days earlier in maturity. It will not produce forage as early as Southland but will produce comparable amounts from November through February, the critical period for green winter forage. The grain quality of Floriland is not equal to Southland. The kernels are red, midsize, midplump, and midlong, with numerous non-twisted awns, and abundant basal hairs. The awns and basal hairs may cause difficulty in drilling. The poor grain quality is not so serious since most of the oats in Florida are used for winter forage.

Table 6.—Disease reaction of Floriland, Southland, and Red Rustproof No. 14 in Florida during 1951 to 1954.

Variety	Victoria blight	Culm rot	Leaf spot	Stem rust	Crown rust
Floriland	R*	S	CS	CS	HR
Southland	R	CS	S	CS	I-CS
Red Rustproof No. 14	R	I	S	CS	CS

* R—resistant, I—intermediate, S—susceptible, CS—completely susceptible.

The superiority of Floriland has been increasing as Southland has been damaged by culm rot and new races of crown rust. Floriland is highly resistant to all races of crown rust known to be prevalent in North America. Data obtained from uniform oat rust nurseries grown throughout the United States indicate it possesses the highest resistance to crown rust of any oat variety now available for commercial production. It is resistant to Victoria blight, but completely susceptible to stem rust and leaf spot.

Application for the registration of Floriland was submitted by W. H. Chapman. Other workers, in addition to those mentioned, who had a part in its development and testing were D. D. Morey, A. T. Wallace, R. W. Earhart, Harland Stevens, R. W. Lipscomb, G. E. Ritchey, and H. W. Lundy. Floriland is a product of cooperative oat breeding investigations between the Florida and Idaho Agricultural Experiment Stations, and the U. S. Department of Agriculture. The origin, description and history of Floriland has been published (3, 11). Additional information on its performance in uniform tests has been reported (6, 7, 8, 9).

VICTORGRAIN 48–93 (Reg. No. 137)

Victorgrain 48–93 (C.I. 5355) originated at the Coker's Pedigreed Seed Co., Hartsville, S. C., in 1946, as a headrow (H.R. 1568) selection of Victorgrain C.I. 4388 (Victoria C.I. 2401 × Fulgrain C.I. 3253). Both the original Victorgrain, and Victorgrain 48–93 reselection, were developed by the late George J. Wilds. The progeny of 1945–46 H.R. 1568 was entered in preliminary strain tests in 1946–47 where it was observed to be relatively more tolerant to *H. victoriae*, under field conditions, than the parent Victorgrain C.I. 4388. Victorgrain 48–93 was first increased in 1947–48 block No. 93 where it again showed tolerance to *H. victoriae*. After further testing the following two seasons, it was designated Victorgrain 48–93 and distributed by the Coker's Pedigreed Seed Co., in 1950.

Victorgrain 48–93 is an attractive, high yielding, stiff-strawed, awnless, plump-grained, medium-early maturing variety, with an unusually wide range of adaptation. It ranked first for yield among 12 named varieties in the Uniform Fall Sown Oat Experiment for 62 stations-years during 1951–53. Victorgrain 48–93 averaged 5 days earlier, 4.3 inches shorter, and was slightly superior in straw strength than Arlington; but was slightly inferior in hardiness and forage production. It has sufficient hardiness for growing throughout the Southeastern Piedmont and Coastal Plain Regions.

Victorgrain 48–93 possesses the typical Victoria resistance to most of the older races of crown rust, such as 202, 203, etc., but is susceptible to some of the newer races, such as 213, 216, etc. It is susceptible in the seedling stage to laboratory and greenhouse tests with *H. victoriae*. Although resistant to the strains of smut increased on Victoria and Fulghum, it has been susceptible to the strains increased on Fulgrain Strain 3. It is susceptible to all races of stem rust.

Application for the registration of Victorgrain 48–93 was submitted by S. J. Hadden for the Coker's Pedigreed Seed Co. He also supplied the information on the origin, history, description, performance and disease reaction. Information on the origin, description, and performance of Victorgrain 48–93 in uniform regional yield nurseries has been published (6, 7, 8, 9, 11).

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Registration of Varieties and Strains of Orchardgrass (*Dactylis glomerata*)[1]

M. A. Hein[2]

POTOMAC is the first variety of orchardgrass that has been approved for registration under the cooperative agreement between the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture and the American Society of Agronomy.[3]

POTOMAC ORCHARDGRASS (Reg. No. 1)

Potomac orchardgrass (*Dactylis glomerata* L.) is a mass selected variety developed at the Plant Industry Station, Beltsville, Md., by the Field Crops Research Branch. The source material for this variety traces to persistent vigorous plants collected in 1935 from old pastures in Maryland, Virginia, and Pennsylvania and isolated plants in strain and mixture trials at the Plant Industry Station. This material was tested in space planted nurseries for vigor, persistence, leafiness and rust resistance and in 1940 selected material was placed in isolation blocks for seed increase. In 1945 plants were again selected from 3-year old broadcast plots and established in an isolated nursery. Potomac orchardgrass represents the third cycle of mass selection. Seed was distributed to most of the Agricultural Experiment Stations, where orchardgrass is adapted, for testing under the name "Beltsville orchardgrass."

Potomac orchardgrass is a dark green, leafy, erect variety similar to commercial seed lots in height. It is somewhat leafier at all stages of growth, and the leaves maintain their green color better with approaching maturity than do the leaves in the commercial type. Potomac is about 3 days later in maturity than commercial, except in the northern latitudes where such differences have not been observed. It is a productive variety that is characterized by superior persistence and rust resistance. Tests with legumes, such as Ladino clover, indicate Potomac is not as aggressive as commercial orchardgrass, thus lends itself well to maintaining a desirable balance with the legume. Potomac has been generally superior to commercial and other varieties in disease resistance; however, it has been observed that in the absence of rust, Potomac will not show up to advantage. Potomac is adapted primarily to the central and southern portions of the orchardgrass belt. Yield data comparing Potomac with commercial and two other varieties are presented in table 1.

Potomac was released in 1954 and is being increased under National Foundation Seed Project. Foundation seed should be available to certified seed growers in 1956 for increase. Additional information on Potomac orchardgrass has been published.[4]

[1] Registered under a cooperative agreement between Field Crops Research Branch, A.R.S., U.S.D.A. and the American Society of Agronomy. Received Sept. 17, 1955.

[2] Principal Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A. Member of the 1955 Committee on Varietal Standardization and Registration charged with the registration of grass varieties.

[3] Report of the Committee on Varietal Standardization and Registration to be published in December 1955 Agronomy Journal.

[4] Crops & Soils, 7(3):23. 1954.

Table 1.—Annual and last cutting yields of orchardgrass strains planted at Beltsville, Md. in the fall of 1949.

Variety	Yield in tons dry matter per acre							
	1950		1951		1952		Average	
	Annual	Last cutting	Annual	Last cutting	Annual	Last cutting	Annual	Last cutting
Potomac	3.17	1.10	4.75	1.35	3.66	0.95	3.86	1.13
Commercial	3.00	0.92	4.35	0.83	3.10	0.43	3.48	0.73
Synthetic I	3.26	1.14	4.67	1.04	3.43	0.66	3.79	0.95
S-143	3.14	1.32	4.24	1.17	3.13	0.82	3.50	1.10
L.S.D.	—	—	—	—	—	—	0.31	0.11

Registration of Sorghum Varieties, VIII[1]

R. E. Karper[2]

THE seventh report on the registration of sorghum varieties was published in November, 1954.[3] Two applications for the registration of new varieties of sorghum have been approved during the past year and the descriptions of these varieties are included in this report.

GREENLEAF, (Reg. No. 105)

Greenleaf is a new variety of Sudangrass which was released by the Kansas Experiment Station. It was selected and tested from 1940 to 1950 by R. C. Pickett and K. L. Anderson and released to certified seed growers in Kansas in 1953. The variety originated from an intercross of Sudangrass strains (Leoti–Sudan 2 × Leoti–Sudan 4) made by J. R. Quinby and R. E. Karper at the Texas Station.

Greenleaf has a sweet and juicy stalk, is leafy, freely tillering, and later in maturity than other present commercial varieties of Sudangrass. The glumes are mahogany colored, and when fully ripe a large percentage of the caryopses will thresh free from the glumes.

Because of lateness in maturity, the plants are vigorous and the yields are high under favorable soil and moisture conditions. Although the growth is slower in the spring than early strains and varieties, Greenleaf has more potential later growth and will remain green and growing longer. The variety is resistant to leaf blight *(Helminthosporium turcicum)* and also to several of the bacterial foliage diseases. The Prussic acid potential is considered as medium-low, not significantly higher than Wheeler, an early strain of Common Sudangrass.

TRACY, (Reg. No. 106)

Tracy is a new mid-season variety of sorgo for sirup production released and distributed by the Mississippi Agricultural Experiment Station in 1953. The variety originated from a cross between White African and Sumac made by H. N. Vinall of the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, in 1923. Selection work that resulted in this variety was performed at the Texas Experiment Station at Chillicothe by H. N. Vinall, J. C. Stephens, and J. R. Quinby and the selection supplied to the U. S. Sugar Plant Field Station at Meridian, Miss., in 1938. Carl Grassl, Botanist, Division of Sugar Plant Investigations, purified the type for final culture and testing by I. E. Stokes and others at the Mississippi Station.

Tracy matures in around 100 days, has erect stalks of medium diameter. The panicle is small, erect, and compact. The glumes are reddish-brown, mostly deciduous at threshing. The seeds are small with a reddish-brown seed-coat and the brown nucellar layer is absent.

Cooperative tests for a number of years show Tracy to be a superior new mid-season variety for sirup production under a wide range of conditions in Mississippi. It is lodging-resistant and the straight stalks handle well at the mill and produce favorable yields of sirup per ton of stalks. A high percentage of juice is recovered, the sugar content of the juice is high and clarification is excellent resulting in light amber colored sirup with a pleasing flavor.

Tracy is comparable to White African in resistance to leaf anthracnose and red rot *(Collectotrichum graminicolum)*, and also to rust and other bacterial foliage diseases.

The variety was named in memory of the late Dr. S. M. Tracy who served during the period 1888 to 1897 as the first director of the Mississippi Agricultural Experiment Station.

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[1] Registered under cooperative agreement between the Field Crops Research Branch, A.R.S., U.S.D.A., and the American Society of Agronomy. Received Sept. 17, 1955.

[2] Agronomist, sorghum investigations, Texas Agr. Exp. Sta., College Station, Tex. Member of the 1955 Committee on Varietal Standardization and Registration charged with the registration of sorghum varieties.

[3] Karper, R. E. Registration of Sorghum Varieties, VII. Agron. Jour. 46:526. 1954.

Registration of Soybean Varieties, V[1]

M. G. Weiss and T. M. Stevenson[2]

THIRTEEN varieties of soybeans have been registered prior to this report, the last report appearing in November 1953.[3] Five varieties, Dortchsoy 67, Dorman, Capital, Harosoy, and Improved Pelican were approved for registration in 1955.

DORTCHSOY 67 (Reg. No. 14)

Dortchsoy 67 originated as a selection from the progenies of a cross between an early maturing selection from Macoupin and Ogden, in the soybean breeding program of the Robert L. Dortch Seed Farms, Scott, Ark., the original cross having been made in 1942. The variety is characterized by a determinate growth habit, pronounced side branching with heavy foliage, white flowers, gray pubescence, dark gray pods at maturity mostly containing 2 or 3 beans, and moderately small beans ellipsoidal to slightly flattened in form, yellow seed coat color, yellow cotyledons, and light brown hilum. It is medium in height and its maturity classification is Group V. It is well adapted to the Mid-South including Arkansas, eastern Oklahoma, northeastern Louisiana, western Mississippi, and western Tennessee and to sections of the coastal plains region in southern Maryland and northeastern Virginia. This area coincides with all but the northern fringe of the area in which S-100 is adapted and, because of the later maturity of Dortchsoy 67, extends slightly southward.

The superior characteristics of Dortchsoy 67 were established in tests conducted by the Robert L. Dortch Seed Farms and it was entered in regional tests in 1951, the year prior to distribution. Regional tests, conducted by Agricultural Experiment Stations of the Southern Region in cooperation with the U. S. Regional Soybean Laboratory, established that Dortchsoy 67 had appreciably higher oil content and seed quality than S-100 (table 1), the variety grown most extensively in its area of adaptation. The shorter, more dense growth habit relative to S-100 gives greater ground cover which results in more effective late-season weed control. Additional information on Dortchsoy 67 has been published (7).

Dortchsoy 67 was distributed by the Robert L. Dortch Seed Farms in 1952 and has been grown fairly extensively as a replacement to S-100.

DORMAN (Reg. No. 15)

Dorman originated as an F_5 plant selection from the progenies of a cross between the Dunfield and Arksoy 2913 varieties in a cooperative program between the Delta Branch of the Mississippi Agricultural Experiment Station and the U. S. Regional Soybean Laboratory. The variety is characterized by determinate growth habit, moderate height, prolific side branching, dense spreading foliage with exceptionally large leaflets, white flowers, gray pubescence, light gray pods at maturity predominantly with 2 or 3 beans per pod, and small, ellipsoidal and slightly flattened beans with yellow cotyledons, and yellow seed coat with a tinge of buff color in the hilum. Dorman is highly resistant to shattering, and its maturity classification is Group V. Its optimum area of adaptation includes the alluvial soils of the Mississippi Valley from southeastern Missouri to northeastern Louisiana, the eastern third of Oklahoma, and the coastal plains soils of southern Maryland and northeastern Virginia. This area coincides with the area in which S-100 has been the predominant variety.

Regional tests, conducted by the Agricultural Experiment Stations of Maryland, Missouri, and states of the Southern Region in cooperation with the U. S. Regional Soybean Laboratory, established that Dorman is appreciably superior to S-100 in oil content, bean quality, ground cover throughout the growing season, and uniformity of ripening (table 1). Although mean yield potentialities on all soil types are comparable to those of S-100, Dorman has given relatively higher yields on the heavy clay soils of the Mississippi Delta area. Additional information on Dorman has been published (8, 9, 10).

Dorman was increased and released cooperatively in the states of Arkansas, Maryland, Mississippi, Missouri, Oklahoma, Tennessee, and Virginia and has replaced S-100 to the limit of available seed.

[1] Registered under a cooperative agreement between the Field Crops Research Branch, A.R.S., U.S.D.A. and the American Society of Agronomy. Received Sept. 17, 1955.

[2] Agricultural Administrator, Field Crops Research Branch, A.R.S., U.S.D.A. Member of 1955 Committee on Varietal Standardization and Registration charged with the registration of soybean varieties, and Chief, Forage Crops Division, Division of Forage Plants, Department of Agriculture, Central Experiment Farm, Ottawa, Canada, respectively.

[3] Weiss, M. G. Registration of Soybean Varieties, IV. Agron. Jour. 45:570–571, 1953.

Table 1.—Mean agronomic and compositional performance of Dortchsoy 67, Dorman and S-100 Soybean varieties in regional tests,* 1951–53.

Variety	Yield, bu. per acre	Relative maturity, days	Lodging, score†	Height, inches	Bean quality, score†	Bean size, g/100	Protein %	Oil %	Iodine value, No.‡
Dortchsoy 67	25.9	+4	2.0	33.3	2.1	11.7	38.9	21.6	132.7
Dorman	24.6	0	2.1	31.8	1.9	12.4	39.5	21.7	135.5
S-100	24.4	0	1.9	41.0	2.8	13.2	42.0	19.9	130.8

* From 17 to 24 locations each year in three years.
† From 1 (erect, excellent) to 5 (prostrate, very poor).
‡ Data from 1951—1952 only.

Table 2.—Mean agronomic and compositional performance of Capital and Mandarin Soybean varieties in regional tests,* 1946–53.

Variety	Yield, bu. per acre	Relative maturity, days	Lodging, score†	Height, inches	Bean quality, score†	Bean size, g/100	Protein %	Oil %	Iodine value, No.‡
Capital	28.8	−0.2	2.6	31.5	2.0	13.0	40.6	20.2	134.5
Mandarin (Ottawa)	28.0	0	1.4	28.5	2.0	18.2	42.2	19.4	131.6

* From 8 to 16 locations each year in eight years.
† From 1 (erect, excellent) to 5 (prostrate, very poor).
‡ Data from 1946–52 only.

CAPITAL (Reg. No. 16)

Capital originated as an F_8 selection from the progenies of a cross between Strain 171 and AK (Harrow) in the soybean breeding program of the Forage Crops Division, Central Experimental Farms, Ottawa, Ontario, Canada. Strain 171 is an early maturing selection from a mixed seed lot obtained in 1931 from J. L. North, Royal Botanic Gardens, London, England, the germ plasm of which had been collected in the vicinity of Sochentze, east of Harbin, Manchuria. AK (Harrow) is a selection made at the Dominion Experiment Station, Harrow, Ontario from the AK variety.

Capital is a moderately tall variety with erect, determinate growth and numerous short side branches. It has purple flowers, tawny pubescence, brown pods at maturity, and predominately 2 to 3 beans per pod. The beans are small, round in shape and have yellow cotyledons, and yellow seed coat color with a light brown hilum and a distinctly dark spot at the micropyle. Capital is classified as Group O maturity, ripening approximately 3 days earlier than the Ottawa strain of Mandarin when grown at Ottawa and approximately the same date at more southern locations. Its region of adaptation extends laterally through central Minnesota and Wisconsin, Northern Michigan, and southeastern Ontario.

Capital has been tested since 1941 at Ottawa and since 1946 in the Group O Regional Tests in the North Central States. Regional test data appear in table 2, showing appreciable superiority over Mandarin (Ottawa)—the variety previously grown in the area of adaptation—in oil content and height and a slight superiority in yield of beans. Yield superiority is greater in tests at Ottawa. Information on Capital has previously been published (1).

Capital was licensed as a new variety in Canada in 1944 and released for production the same year. It is presently grown extensively throughout southeastern Ontario, and Central Minnesota and Wisconsin.

HAROSOY (Reg. No. 17)

Harosoy originated as a BC_1 selection from the progenies of a backcross Mandarin × (Mandarin × AK) in the soybean breeding program of the Dominion Experimental Farm, Harrow, Ontario, Canada. The variety is characterized by upright determinate growth, short branches held closely to the main stem, light green foliage with upper leaflets tending to have acute points, purple flowers, gray pubescence; pods borne well off the ground, medium light brown in color at maturity, predominately 2 to 3 seeded and resistant to shattering; beans round in shape, of medium size, and having yellow cotyledons, yellow seed coat with a yellow hilum and bearing a slight brownish tinged spot at the micropyle. Harosoy matures approximateley 3 days earlier and exhibits greater field resistance to stem canker than Hawkeye. In maturity it is classified as Group II and its optimum area of adaptation extends from northeast Nebraska and southeast South Dakota eastward through the northern regions of Iowa, Illinois, Indiana, and Ohio and the southwestern area of Ontario.

After superiority of Harosoy was established at Harrow, it was entered in 1951 in regional tests conducted cooperatively by the Agricultural Experiment Stations of the North Central Region and the U. S. Regional Soybean Laboratory. Regional data (table 3) show Harosoy has a slight yield advantage over Hawkeye even though it matures approximately 3 days earlier which permits it to be grown in shorter season areas than the northern limits of the Hawkeye adaptation belt. Although it is earlier in maturity, its plant height is slightly in excess of Hawkeye which is of importance particularly in light soils and at late planting dates. Information on Harosoy has previously been published (3, 11, 12). Harosoy was increased by the Dominion Experimental Farm and distributed to growers in 1951. Its acreage is increasing and it has replaced Hawkeye acreage particularly in the eastern belt of its adaptation.

Table 3.—Mean agronomic and compositional performance of Harosoy and Hawkeye Soybean varieties in regional tests,* 1951–53.

Variety	Yield, bu. per acre	Relative maturity, days	Lodging, score†	Height, inches	Bean quality, score†	Bean size, g/100	Protein %	Oil %	Iodine value, No.‡
Harosoy	32.5	−3	1.8	38	1.7	16.8	40.4	20.5	132.7
Hawkeye	31.6	0	1.6	37	1.5	16.9	41.3	20.8	130.5

* From 23–25 locations each year in three years.
† From 1 (erect, excellent) to 5 (prostrate, very poor).
‡ Data for 1951–52 only.

IMPROVED PELICAN (Reg. No. 18)

Improved Pelican was developed from an F_4 plant selection from the progenies ofa cross between the Tanloxi and PI 60406 soybean varieties by the Louisiana Agricultural Experiment Station. It was developed particularly for the sugar cane area of Louisiana and other sections requiring high yields of forage when soybeans are used for soil improvement or for hay. It combines with high forage yields the desirable bean characteristics of yellow seed coat color, satisfactory bean yields and high oil content, characteristics which were lacking in previously grown varieties suitable for soil improvement and hay uses. The combination of characters permits growing of one variety regardless of intended use thereby providing flexibility for the grower's program.

Improved Pelican has a tall, upright, indeterminate type of growth frequently attaining a height of 5 or 6 feet. Subsequent lodging often lowers the height to 3 or 4 feet but provides excellent ground cover for weed control throughout the growing season. It has purple flowers, tawny pubescence, yellow pods which contain 2 or 3 seeds and are resistant to shattering, moderately small beans ellipsoidal and slightly flattened with yellow cotyledons, and yellow seed coat color with a large, prominent brown hilum. Its maturity classification is Group VIII and its optimum area of adaptation seems confined to Louisiana and areas of adjacent states in the Gulf area. Additional information on Improved Pelican has been published (2, 4, 5, 6).

Forage production tests conducted by the Louisiana Agricultural Experiment Station show forage yields of Improved Pelican are approximately equal to those of Pelican and Acadian, two previously released varieties which have not become widely established, and far superior to varieties developed previously for bean production. Regional variety tests conducted cooperatively by the Agricultural Experiment Stations of the Gulf Coast States and the U. S. Regional Soybean Laboratory comparing bean production of Improved Pelican relative to varieties developed predominately for bean production indicate the new combination variety is higher in yield than Mamotan, similar to J.E.W. 45, and approximately 90% as high as Jackson. Oil content of Improved Pelican exceeds all but Jackson. In comparison of oil content with other hay or combination varieties, Improved Pelican is the equal of Acadian, appreciably higher than Pelican, and far superior to other hay varieties previously grown.

Improved Pelican was increased by the Louisiana Agricultural Experiment Station and distributed to growers in 1950. Acreage for soil improvement in the sugar cane area of Louisiana is increasing as rapidly as seed supplies will permit. Hay and bean production acreage also is increasing in the Gulf Coast region, particularly central Louisiana and southern Alabama.

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Registration of Improved Wheat Varieties, XX[1]

Fred N. Briggs[2]

SEVENTY-SEVEN varieties of wheat have been registered previous to this report, the last appearing in 1952.[3]

ONAS 53, (Reg. No. 348)

Onas 53 (C.I. No. 13069) was developed by the California Agricultural Experiment Station and the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture. Information regarding it was furnished by C. A. Suneson and C. W. Schaller. The original Onas, introduced from Australia, was first grown commercially in California in 1924. Successive backcross improvement programs produced bunt resistant Onas 41 (1), Awned Onas with improved yield and test weight (2), and a combination of the two, Onas 49.

Onas 53 is composite of 250 F_3 lines derived from Kenya (P.I. 117526) $\times$ Onas 49[7]. The initial cross with Kenya was made in 1944. By growing two crops per year, the combination of previous breeding gains with rust resistance was completed in 1951. Five test crops for agronomic, disease, and quality evaluation were grown from 1951 to 1953. These reaffirmed the close likeness to the recurrent parent shown by many other tests with similarly improved varieties tested from 1937 to 1953, and provided a precise difference due to stem rust (3).

Onas 53 has shown greater resistance than Baart 46 or Kentana 48 when exposed to California cultures of stem

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[3] Briggs, Fred N. Registration of Improved Wheat Varieties, XIX. Agron. Jour. 44:155. 1952.

Table 1.*—Yields of Quanah and four other commercial varieties at Texas Substations, 1945–50.

Location	Number years tested	Yield of grain, bushels per acre				
		Quanah	Comanche	Westar	Wichita	Triumph
Denton	6	21.5	18.9	19.4	15.5	16.9
Greenville	3	20.9	18.5	—	17.5	18.5
Temple	3	23.0	16.2	—	3.8	6.4
Comfort	2	23.0	14.4	—	6.1	—
Stephenville	3	24.6	19.7	17.6	14.5	13.4
Spur	3	15.1	19.1	16.8	18.0	18.0
Iowa Park	4	33.5	33.1	31.9	33.4	30.8
Chillicothe	5	30.7	30.2	31.8	30.1	28.0
Amarillo	3	23.7	25.3	24.9	23.8	24.3

* Taken from "Quanah Wheat", Texas Agr. Exp. Sta. Bul. 734.

rust races 11, 17, and 56. It is recommended state-wide under irrigation or where rainfall will sustain later than average maturity, but not in extreme shatter-hazard areas (4).

QUANAH WHEAT, (Reg. No. 349)

Quanah wheat (C.I. 12145, Selection 171–43–29) was originated at the Denton Substation of the Texas Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture. The variety was developed from a complex cross in which the F_1 plants of two crosses involving Comanche were crossed. The parentage was (Comanche × Honor–Forward, Cornell 501e–I–28, F_1) × (Mediterranean–Hope, 41–33–1–J13 × Comanche, F_1). The cross and selection which was named Quanah were made by I. M. Atkins.

Quanah is a hard red winter wheat having milling and baking characteristics very similar to its Comanche parent. It is resistant to many races of leaf and stem rust but not to race 15B or several other races which have recently become prevalent. It is resistant to the races of bunt which are generally prevalent in the midwest but is extremely susceptible to loose smut.

The variety is less winter-hardy than its Comanche parent so is recommended only in the Central and Rolling Plains areas of Texas. It was distributed in 1951 and is grown largely in Central Texas.

Yields of Quanah wheat in comparison with other commercial varieties at several Texas stations are given in table 1.

FRISCO WHEAT, (Reg. No. 350)

Frisco wheat (C.I. 13106, selection 131–46–3) was originated at the Denton Substation of the Texas Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture. The variety was developed from the cross (Fronteira × Red May) × Red May. The Red May parent was a local strain grown in the Dallas area of North Central Texas for more than 100 years. The cross and selection were made by I. M. Atkins.

Frisco is an early maturing, soft red winter wheat similar in milling and baking characteristics to the Red May wheat that has been used in producing family-type flour in the North Central Texas area for many years. The variety is superior to the old local strain in resistance to leaf and stem rust. It is not resistant to stem rust race 15B and some other races that recently have become important.

Table 2.—Yields of Frisco wheat and two commercial varieties at Texas Substatians, 1949–53.*

Location	Number years tested	Yield of grain, bushels per acre			L.S.D.
		Frisco	Red May	Mediterranean	
Denton	4	25.6	24.1	24.2	2.4
Greenville	4	29.3	27.7	27.4	3.7
Sherman	2	38.1	35.8	29.5	5.6
Stephenville	1	23.7	13.0	10.5	3.0
Temple	5	26.1	17.4	17.7	2.0
McGregor	1	22.0	20.5	20.6	4.4
Comfort	4	27.2	17.3	16.6	2.7

* Taken from "Frisco Wheat", Texas Agr. Exp. Sta. Progress Report 1682, May 11, 1954.

The new variety is recommended for a rather limited area in North Central Texas.

Yields of Frisco in comparison with other commercial varieties at several Texas stations are given in table 2.

CONCHO, (Reg. No. 351)

Concho wheat (C.I. 12517) was developed by the Oklahoma Agricultural Experiment Station and the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, from the cross Comanche × Blackhull–Hard Federation. It was bred and introduced by A. M. Schlehuber.

Average yields of Concho and the three varieties—Triumph, Pawnee, and Comanche—most widely grown in Oklahoma and tested during all or a part of the period 1949 to 1954 are shown in table 3. In the nursery tests grown at Stillwater, Woodward, and Cherokee for the entire 6-year period, Concho outyielded Comanche by 4.8 bushels and Pawnee by 6.7 bushels. In the variety test for 17 station years grown at Goodwell in addition to the other 3 locations for 1950 and 1954, Concho outyielded Comanche, Pawnee, and Triumph by 4.7, 6.6, and 6.8 bushels, respectively. In the State-wide Nurseries for the period 1950 to 1954 Concho significantly outyielded the other recommended varieties in both western and eastern Oklahoma. For all tests in Oklahoma, including 88 station-years, Concho has yielded 16% more than Comanche and 22% more than Pawnee and Triumph. Concho has outyielded other recommended varieties in every section of the state.

Table 3.—Comparative acre yields in bushels of Concho, Comanche, Pawnee, and Triumph in Oklahoma, 1949–54.

Variety	Nursery tests* 18 station years		Variety tests† 17 station years		Experiment station tests‡ 35 station years		Western Oklahoma§ 38 station years		Eastern Oklahoma¶ 15 station years		Average of all tests 88 station years		Percent of Comanche same years
	Ave.	Rank	Ave.	Rank	Ave.	Rank	Ave.	Rank	Ave.	Rank	Ave.	Rank	
Concho	30.4	1	27.7	1	29.1	1	26.3	1	26.9	1	27.5	1	116
Comanche	25.6	2	23.0	2	24.3	2	22.8	2	25.1	2	23.8	2	100
Pawnee	23.7	3	21.1	3	22.4	3	22.3	4	21.8	3	22.3	3	94
Triumph	—	—	20.9	4	—	—	22.7	3	21.7	4	—	—	94

* Uniform yield nurseries: at Stillwater, Woodward, and Cherokee, 1949–1954.
† Variety tests: at Stillwater, Woodward, Cherokee, and Goodwell, 1950–1954.
‡ Weighted average of variety tests and uniform yield nurseries.
§ State-Wide nurseries: total of 12 locations, 1950–1954.
¶ State-Wide nurseries: total of 7 locations, 1951–1954.

Table 4.—Comparative test weights of Concho, Comanche, Pawnee, and Triumph in Oklahoma, 1949–54.

Variety	Nursery tests 18 station years*	Variety tests 15 station years†
	Pounds	Pounds
Concho	60.22	60.81
Comanche	58.70	59.21
Pawnee	58.89	58.89
Triumph	‡	60.61

* Six years each at Stillwater, Woodward, and Cherokee, 1949–1954.
† Five years each at Stillwater, Woodward, and Cherokee, 1950–1954.
‡ Triumph not grown in nursery tests in 1953 and 1954.

Concho has produced grain of high test weight under most conditions. Comparative test weights are shown in table 4. In the nursery tests grown at Stillwater, Woodward, and Cherokee from 1949 through 1954, Concho exceeded Pawnee by 1.33 pounds per bushel and Comanche by 1.52 pounds. In the variety tests grown 5 years each (1950–54) at the 3 locations, Concho exceeded the test weight of Pawnee by 1.92 pounds, of Comanche by 1.60 pounds, and of Triumph, a high test weight variety, by 0.20 pound.

The data in table 5 show the reaction of Concho and 7 other varieties to the major diseases encountered in Oklahoma. In most instances, Concho is more resistant than the other varieties now being grown.

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Table 5.—The disease reaction of Concho compared with several other winter wheat varieties.

Variety	Reaction to:							
	Leaf rust	Stem rust	Bunt	Loose smut	Yellow streak mosaic	Soil-borne mosaic	Leaf blotch	Root rot
Cheyenne	VS*	VS	S	—	VS	VS	MR	VR
Comanche	S	S	VR	MR	VS	R	MR	MR
Concho	VR	VS	VR	MR	MT	R	MR	MR
Pawnee	S	S	MR	VR	VS	MS	MS	MS
Ponca	VR	S	S	VR	VS	MS	MR	S
RedChief	VS	VS	VS	VS	VS	VS	R	MS
Triumph	VS	VS	S	VR	MS	VS	VS	S
Westar	VR	VS	S	MR	S	R	VS	R

* VR = Very resistant; R = Resistant; MR = Moderately resistant; VS = Very susceptible; S = Susceptible; MS = Moderately susceptible; MT = Moderately tolerant.

Registration of Varieties and Strains of Wheatgrass, II (*Agropyron* Spp.)[1]

M. A. Hein[2]

THIS is the second report on the registration of varieties and strains of wheatgrass (*Agropyron* spp.) according to the revised classification[3] of forage crops for registration purposes by Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture and the American Society of Agronomy. The first report was published in 1951.[4]

NORDAN CRESTED WHEATGRASS (Reg. No. 2)

Nordan, a variety of standard crested wheatgrass, *Agropyron desertorum* (Fisch.) Schult. was developed cooperatively at the Northern Great Plains Field Station, Mandan, N. Dak. by the Field Crops Research Branch, Agricultural Research Service, and the former Division of Nurseries, Soil Conservation Service.

The original selection for Nordan was made on the experiment station at Dickinson, N. Dak. in 1937. Vigorous, erect, leafy plants with large awnless seeds were then selected under open pollination during a period of two generations. Seed of seven plants from the best open pollinated line resulting from these selections was bulked for increase and yield tests. First yield data was collected in 1944. Since that time new tests have been established each year to compare it with commercial lots and strains of local origin or from other sources. It has been designated in past tests as Mandan 571.

Nordan is similar in general appearance to commercial Standard but is quite different in a number of characteristics that made it more desirable than commercial. Plants are more uniform but variability is high enough to suggest a wide range of adaptation. Most plants are erect and leafy and are less likely to lodge when grown for seed production. Heads are more uniform and compact than those of commercial and the seed is more uniform and higher in test weight and quality. There is also less awn which improves threshing, cleaning and drilling qualities. Seedling vigor of this new variety is superior with stands being established more uniformly and rapidly than those of commercial.

Table 1.—Comparative seed and forage yields of Nordan and commercial Standard crested wheatgrass at Mandan, N. Dak.

	1951	1952	1953	Average
	Tons of dry forage per acre			
Nordan	——	2.85	3.50	3.18
Commercial Standard	——	2.85	3.42	3.14
	Pounds of seed per acre			
Nordan	748	432	534	571
Commercial Standard	612	361	453	475

Seed and forage yields are as good or somewhat better than those of commercial Standard as shown in table 1. The primary justification for the release of Nordan, however, is its superiority in plant type, quality of seed, and seedling vigor which results in greater ease in handling and in establishing stands.

Another important characteristic of Nordan is its purity for the Standard type. Much of the commercial Standard now grown contains a mixture of Fairway which has been found in many tests to be inferior. Since this is the first distinct strain of Standard to be released for use in this country it will be one of the few sources of pure seed of the Standard type.

Foundation seed is maintained by the North Dakota Agricultural Experiment Station, and is available to commercial growers. Additional information on Nordan crested wheatgrass has been published.[5]

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[1] Registered under a cooperative agreement between Field Crops Research Branch, A.R.S., U.S.D.A. and the American Society of Agronomy. Received Sept. 17, 1955.

[2] Principal Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A. Member of the 1955 Committee on Varietal Standardization and Registration charged with the registration of grass varieties.

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Registration of Varieties and Strains of Other Grasses, II[1]

M. A. Hein[2]

THIS is the second report on the registration of other grass varieties. Starr Millet was the first grass registered under this classification.[3]

GREEN STIPAGRASS (Reg. No. 2)

Green stipagrass is an improved variety of green needlegrass (*Stipa viridula* Trin.) or feather bunchgrass as it is sometimes known. It was developed and released cooperatively by the Field Crops Research Branch, Agricultural Research Service, the former Division of Nurseries, Soil Conservation Service, U. S. Department of Agriculture, and the North Dakota Agricultural Experiment Station.

This highly uniform variety traces to a single plant selection made in a bulked lot of seed collected from a native stand near Mandan, N. Dak., in 1935. Since all plants in the field collection were highly self fertilized, selections were continued on a pure line basis for two generations. The line with the largest most vigorous plants was selected for increase and testing.

Green stipagrass is superior to a large number of field collections made throughout the Great Plains area and tested at Mandan. Its superiority consists primarily of greater vigor and increased forage yields. It is also more leafy and erect than many other strains. Observations made at Akron, Colo., and Albuquerque, N. Mex., showed it to be well adapted at these locations. It has also been reported to do well as far north as Saskatoon, Saskatchewan.

This grass has been one of the highest yielding cool-season grasses tested at Mandan. Comparative forage yields with crested wheatgrass and with a general field collection of green needlegrass are given in table 1. Seed yields of green stipagrass when grown in rows are high, often well above 500 pounds per acre. When grown as hay or pasture, regrowth is rapid after defoliation. Both hay and pasture are palatable and nutritious.

Seedling vigor is excellent and seed can be planted at a greater depth than that of many other grasses. The seedlings are stiff and erect with the ability to withstand considerable abuse from soil blowing or grasshopper attacks. New seed is relatively dormant, ordinarily germinating less than 20%. This dormancy can be overcome by moist chilling before planting or by holding the seed in storage for a period of at least 3 years. Viability holds up well for 10 years or more. When new seed is used, fall plantings are recommended so that natural freezing and thawing will break the dormancy and result in spring establishment.

Green stipagrass was first released in 1946. Commercial sources of seed are now available. Additional information on the characteristics of this grass have been published.[4]

Table 1.—Forage yields of green stipagrass in comparison to those of a field collection of green needlegrass and to standard crested wheatgrass at Mandan, No. Dak.

	Tons of dry forage per acre			
	1947	1948	1949	Ave.
Green stipagrass	0.34	1.16	1.85	1.12
Green needlegrass (field collection)	0.26	0.99	1.63	0.96
Standard crested wheatgrass	0.12	0.51	1.30	0.64

TUALATIN TALL OATGRASS (Reg. No. 3)

Tualatin, a selection from common tall oatgrass (*Arrhenatherum elatius* (L.) Presl.) was developed at the Oregon Agricultural Experiment Station, in cooperation with Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture. The first selections were made in 1930 in an attempt to develop a strain for non-shattering seed characteristics.

Tualatin is leafier, finer stemmed, not quite as tall, and about 10 days later in heading than common tall oatgrass. It is highly resistant to head smut which readily attacks the commercial type. Forage yields are equal under comparable growing conditions, and seed yields considerably higher due to its resistance to shattering, than common tall oatgrass.

Table 2.—Comparative forage and seed yields of Tualatin and common tall oatgrass at Corvallis, Oreg.

Varieties	1938	1939	1940	1941	4 yr. Ave.	1951	1952	1953	3 yr. Ave.
				Tons dry forage per acre					
Tualatin	2.53	1.94	1.07	1.41	1.74	2.94	3.36	2.11	2.80
Common	2.36	1.86	1.03	1.29	1.63	3.04	3.45	1.77	2.75
				Pounds seed per acre					
Tualatin	500	467	367	293	407	583	493	363	480
Common	285	130	155	130	175	282	428	259	323

[1] Registered under a cooperative agreement between the Field Crops Research Branch, A.R.S., U.S.D.A. and the American Society of Agronomy. Received Sept. 17, 1955.

[2] Principal Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A. Member of the 1955 Committee on Varietal Standardization and Registration charged with the registration of grass varieties.

[3] Hein, M. A. Registration of Varieties and Strains of Pearl Millet (*Pennisetum glaucum* (L.) R. Br.) Agron. Jour. 45:573. 1953.

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Under favorable conditions, it is a long-lived perennial, has a bunch type growth, from 4 to 6 feet in height, quite leafy at the base. Leaves are medium coarse as are the stems or stalks. The heads are usually somewhat more compact than those of the common tall oatgrass. Forage and seed yield data comparing Tualatin and common tall oatgrass are presented in table 2.

Seed of Tualatin tall oatgrass was first distributed in 1940 and is commercially grown. Additional information on Tualatin tall oatgrass has been published.[5,6,7]

[5] U.S.D.A. Yearbook of Agriculture, p. 1053, 1937.

[6] U.S.D.A. "Grass" Yearbook of Agriculture, p. 654, 1948.

[7] Hafenrichter, A. L., Mullen, L. A., and Brown, R. L. U.S.D.A. Misc. Pub. No. 678, p. 6.

Book Reviews

RADIOISOTOPES IN BIOLOGY AND AGRICULTURE

Principles and Practice

By C. L. Comar; New York, McGraw-Hill Book Co., Inc., 481 pp. 1955. $9.00.

This is an admirable volume containing a wealth of information and advice for those investigators in biology or the agricultural sciences who may be considering experimentation involving radioisotopes. The author take a realistic viewpoint. He is not an evangelist advocating the adoption of radioisotope techniques as the panacea for all investigational difficulties in these fields. Through examples drawn from diverse fields he has attempted to explain the advantages and disadvantages inherent in the use of radioisotopes, their possibilities and their limitations. Later chapters deal with such topics as the practical problems of health physics, the facilities required for work with plants and animals, the characteristics of selected isotopes most likely to be useful in biological studies, autoradiography, radioactivation analysis, and ancillary methods such as paper chromatography and ion exchange. The book concludes with a glossary of selected terms in nuclear science and a summary of radioisotope preparations available from the Oak Ridge National Laboratory.

The book is somewhat uneven with respect to details of procedures, and the reasons for the author's choice of procedures described fully are not always apparent. In many cases it is probable that the selection was somewhat arbitrary, but in keeping with the objective of supplying sufficient illustrative examples so that an investigator can determine the suitability of a particular procedure to his particular problem and if it is within the scope of his facilities and experience. Applications in soil science and plant physiology are perhaps less well covered than those in some other areas. Even so, this book should be of great value to soil and crop scientists contemplating work involving radioisotopes, and particularly if their problems lead them beyond the rather well-worn paths of P^{32}.—A. G. NORMAN.

CLIMATES IN MINIATURE

By T. Bedford Franklin, New York, Philosophical Library, Inc. 137 pages, illus. 1955. $3.75.

This small book is primarily a record of observations and results of experiments by the author in his garden during most of his life. He emphasizes the temperature component of microclimate in relation to habitat of some common plants, insects, and animals. The book is not intended as a scientific treatise on microclimate but rather as an introduction to an interesting hobby. The author disclaims professional competence in the subject but it is obvious that he is familiar with some of the literature, has keen powers of observation and an inclination to experiment. Agronomists will find the book interesting and stimulating even though they might be unwilling to accept some of the author's conclusions.—R. J. GARBER.

CONTRIBUTIONS TO PLANT ANATOMY

By Irving W. Bailey, Waltham, Mass., Chronica Botanica Co. New York, Stechert-Haffner. (Volume 15 of Chronica Botanica) XXV + 260 pp. frontisp. and 23 plates. 1954. $7.50.

As stated in an introductory biographical sketch of Professor Bailey by Elso S. Barghoorn, "it is the purpose of this volume to draw together and to make more readily accessible certain selections of Professor Bailey's work which are representative of the breadth and depth of his scientific interests, and also to make better known among students of plant life the many facets of his personality as a botanist and as a scientist". The book is essentially a selection of the published papers of the author made by the author himself and "arranged to illustrate successive attempts between 1909–1953 to bridge gaps between Plant Anatomy and other fields of scientific endeavor".

The 20 chapters of the book, each a published paper of the author, are grouped into 8 parts, namely, I, Cytology and Ontogeny, II, Biochemistry and Biophysics, III, Phylogeny, IV, Taxonomy, V, Entomology, VI, Paleobotany, VII, Wood Technology, and VIII, Cooperation in Scientific Research. There is a bibliography consisting of 113 of the author's papers published between 1909 and 1953. There is also a 6-page list of references to the work of others, an index of plants and animals, as well as an author index and a subject index.

The volume will stand as a permanent monument to Professor Bailey although it represents only a very small part of the excellent contributions of the author to plant anatomy.—H. W. POPP.

MENTION

The New Grassland-Livestock Handbook, 1955 revision by the Joint Committee on Grassland Farming, Norman, Okla., the University of Oklahoma Press. More than 50 specialists from state experiment stations, cooperating professional organizations, and industries serving agriculture have contributed to this handbook. Its 48 pages cover the following topics: Grassland for long profits, establishing a grassland program, pasture: foundation of the grassland program; hay, grass silage, crop processing containers and storage structures, and machinery.

The Role of Organic Matter in Soil Fertility, by N. R. Dhar, Institute of Microbiology, Uppsala, Sweden, now of Allahabad University, India. Reprint from The Annals of the Royal Agricultural College of Sweden, Vol. 21.

A Simplified Handbook on Soils, Phosphates, and Mixed Fertilizers, by Vincent Sauchelli, Director, Agricultural Research, Davison Chemical Co., Division of W. R. Grace & Co., published by the company, Baltimore, Md. This 32-page brochure deals with fertilizer chemistry in lay terms and is designed to give in simple, non-technical language practical information on soil fertility and crop nutrition. Included are soil moisture supply, crop water requirements, how plants feed, chemical fertilizers, plant constituents, plant nutrients, humus, soil amendments, trace elements, use of fertilizers, and other topics.

Manual of Plant Breeding (Handbuch der Pflanzenzüchtung) in German, Berlin and Hamburg, Verlag Paul Perey. The first monthly issue of this second edition of the standard work appeared in June 1955. It will be published in six volumes: I, Principles of Plant Breeding; II, Breeding of Cereals; III, Bulbous and Root Crops; IV, Forage Crops; V, Special Crops; and VI, Fruit, Vegetable, Vines, and Forest Tree Plants. H. K. Hayes, University of Minnesota, assisted the editors in soliciting U. S. contributors among whom are the following:

Vol. II, Cereal Breeding—E. R. Ausemus, F. A. Coffman, J. G. Martin, E. A. Sears; Vol. IV, Forage Crop Breeding—W. M. Myers; Vol. V, Special Crops—T. H. Goodspeed, H. W. Johnson, Kenneth Keller, and W. D. Valleau.

Agronomic Affairs

MEETINGS

Nov. 30—Joint Committee on Grassland Farming collaborating with the Entomological Society of America, Cincinnati, Ohio.

Dec. 5—North-central Weed Control Conference, Omaha, Nebr.

Dec. 5–7—Agricultural Ammonia Institute, Kansas City, Mo.

Dec. 15–16—First annual Beltwide Cotton Production Conference, Memphis, Tenn.

Dec. 26–31—National Association for the Advancement of Science, Atlanta, Ga.

Dec. 28–30—American Phytopathological Society, Atlanta, Ga.

Jan. 4–6—Weed Society of America, charter meeting, New York, N. Y.

Jan. 16–18—Southern Weed Conference, New Orleans, La.

Feb. 6–8—Southern Branch, American Society of Agronomy, meeting with the Southern Agricultural Workers 53rd annual meeting, Atlanta, Ga.

Feb. 15–17—Western Weed Control Conference, Sacramento, Calif.

Mar. 5–7—Midwest Regional Turf Conference, Lafayette, Ind.

SOUTHERN BRANCH MEETS FEB. 6–8 AT ATLANTA

Jan. 1 is the deadline for submitting abstracts of papers to be presented at the annual meeting of the Southern Branch of the American Society of Agronomy. The branch will meet as the Agronomy Section of the Association of Southern Agricultural Workers Feb. 6–8 in the Atlanta Biltmore Hotel, Atlanta, Ga.

Three copies of the abstract should be forwarded directly to W. E. Colwell, branch secretary, at the agronomy department, North Carolina State College.

Officers of the Southern Branch are Fred H. Hull, University of Florida, president; J. Fielding Reed, American Potash Institute, Atlanta, vice president and chairman of soils; John Gray, Louisiana State University, chairman of crops; and W. E. Colwell, secretary.

WADLEIGH NAMED CHIEF OF SWCRB

C. H. Wadleigh is the new chief of the USDA Soil and Water Conservation Research Branch, Byron T. Shaw, ARS administrator, has announced.

Prior to his appointment, Dr. Wadleigh had served as head of the Section of Soil and Plant Relations since the section was established in 1954. He previously was with the U. S. Salinity Laboratory, Riverside, Calif., and from 1951 to 1954 he was head of the Division of Sugar Plant Investigations at Beltsville.

Dr. Wadleigh is a native of Gilbertsville, Mass., and a graduate of the University of Massachusetts. He has a M.S. degree in horticulture from Ohio State University and the Ph.D. degree in plant physiology from Rutgers University. He was a member of the agronomy staff of the University of Arkansas for 5 years prior to his employment with USDA.

ERIC WINTERS IS TENNESSEE ASSOCIATE DIRECTOR

Eric Winters, head of the agronomy department at the University of Tennessee since 1945, has been appointed associate director of the Tennessee experiment station. Dr. Winters is editor-in-chief of the *Soil Science Society of America Proceedings*. He succeeds John A. Ewing, who is now senior vice dean and senior vice director of the college of agriculture, the experiment station and the extension service at the University of Tennessee.

Prof. Lawrence N. Skold, associate professor of agronomy, is serving as acting head of the agronomy department.

Dr. Winters is a native of Illinois and has been with the Tennessee agronomy department since 1938. Prof. Skold, who has been with the department since 1947, is completing work for the Ph.D. degree at the University of Minnesota.

FIRST PRESIDENT OF COTTON COUNCIL DIES

Oscar Johnston, 75, founder and first president of the National Cotton Council, died Oct. 3 at Greenville, Miss. He died 15 days before the dedication of the Oscar Johnston Cotton Foundation Building at Memphis, Tenn., the new headquarters of the National Cotton Council.

Mr. Johnston proposed the organization of the Council in 1938, and by 1941 all segments of the industry—producers, ginners, cottonseed crushers, warehousemen, merchants, and spinners—had joined the organization. He served as president from 1939 to 1948. An attorney and a banker, Mr. Johnston also supervised the operation of the Delta and Pine Land Co., Scott, Miss., one of the world's largest plantations. He served with the USDA Agricultural Adjustment Administration and Commodity Credit Corporation in 1933 and 1934.

HOMER TISDALE DIES IN ALABAMA

Homer B. Tisdale, a veteran of 42 years' service at Alabama Polytechnic Institute, died at Auburn Oct. 19 following a heart attack earlier in the day.

The 65-year-old plant breeder contributed greatly to Alabama agriculture by his development of new crop strains bred to Alabama conditions. His early years included breeding work with cotton, corn, oats, legumes, and sweet potatoes. Devoting full time to cotton breeding in later years, Mr. Tisdale developed several Cook strains, among them being No. 144 and No. 304, which become widely accepted. He played a major role in planning and initiating the first one variety community cotton improvement association. In 1952, the Experiment Station released Auburn 56, considered to be his greatest contribution to the cotton grower.

A native of Alabama, Mr. Tisdale entered Alabama Polytechnic Institute as a sophomore in 1908 following graduation from a district agricultural school at Evergreen, and received his B.S. degree in 1911. After teaching school a year at Hamilton, Ala., he returned to Auburn to enter the School of Agriculture, receiving his B.S. degree in 1913. Two years later he received the M.S. degree. He did graduate work at Cornell University, returning to Auburn in 1917.

Surviving are his widow, two daughters, Mrs. Ben Suttle of Washington, D. C., and Mrs. Charles Flowers of Atmore, Ala.; and a son, Homer B. Jr., a student of Alabama Polytechnic Institute.

W. H. MACINTIRE RETIRES FROM TENNESSEE STAFF

W. H. MacIntire retired in August following 43 years at the University of Tennessee agricultural experiment station. He served for many years as head of the station's chemistry department.

Dr. MacIntire is a native of North Carolina and has degrees from North Carolina State College, Pennsylvania State University, Cornell University, and Clemson College.

Under his leadership, a program of fertilizer development, with emphasis on phosphate, reached its greatest progress at the Tennessee station in cooperation with TVA. He has done extensive work with fluorine in soils, water, vegetation, and atmosphere. Dr. MacIntire is a Fellow of the American Society of Agronomy.

TWO WYOMING AGRONOMISTS RESIGN

At the University of Wyoming, William F. Spencer, agronomist and soil scientist, resigned Oct. 24 to become project leader in charge of soil and water management research at the Southwestern Irrigation Field Station, Brawley, Calif. On Dec. 2 Jesse L. Mellor, agronomist in charge of soils teaching and research at Wyoming, will resign to join the Olin Mathieson Chemical Co.

INDIAN STUDENT SOCIETY ELECTS OFFICERS

New officers of the student Agronomy Society of the Allahabad (India) Agricultural Institute are announced as follows:

B. N. Gangopadhya, president; S. N. Bhargava, vice president; B. S. Tiwari, treasurer; M. C. Lodha, secretary; and N. S. R. N. Dey, staff adviser. B. N. Bangopadhya was first prize winner of the society's essay contest last year, writing on the subject, "What Agronomic Science Can Do for India."

SORBONNE IS SITE OF 1956 SOIL SCIENCE CONGRESS

Meetings of the 6th Congress of the International Society of Soil Science will take place at the Sorbonne in Paris, France, Aug. 20 to Sept. 8, 1956, according to A. Oudin, chairman of the organizing committee of the society. During the Congress there will be a 1-day excursion into the Paris region. Several 1-week excursions to run simultaneously are also being planned to different places in France.

O. R. MATHEWS RETIRES

OSCAR R. MATHEWS retired Sept. 30 after more than 46 years of service in the USDA. At the time of his retirement he was with the Western Soil and Water Management Section of the SWCRB at Beltsville, Md.

Following his retirement, Mr. Mathews accepted a 1-year assignment effective Oct. 21 with the Medjerdah Valley Commission to serve as consultant for the development of the Medjerdah Valley in Tunisia. He is stationed at Tunis.

NEWS ITEMS

VICTOR L. SHELDON, formerly assistant professor of soils at the University of Missouri, has joined the agronomy staff of Olin Mathieson Chemical Corp. as agronomist for the company's north central district at St. Louis, Mo. LEE R. HANSEN has been named sales supervisor of the Pacific Northwest area for Western Fertilizer Division of Olin Mathieson with headquarters at Portland, Oreg.

—A—

LOREN L. DAVIS, former University of California extension agronomist at Davis, is on leave as ICA crop production advisor to the government of India at New Delhi.

—A—

JOHN W. BROWN, soil chemist of the U. S. Salinity Laboratory, Riverside, Calif., is on 2-year leave with the Institute of Inter-American Affairs and the Servicio Interamericano de Cooperacion Agricola en Panama to organize and supervise the operation of a soil laboratory to implement programs in soil survey, fertility, and management.

—A—

PRYCE B. GIBSON has moved from Alabama Polytechnic Institute, where he was associate plant breeder and associate professor of agronomy, to Clemson Agricultural College, Clemson, S. C., as geneticist with the USDA Forage and Range Section. He is working on improvement of perennial clovers with emphasis on white clover.

—A—

The Nitrogen Division of Allied Chemical and Dye Corp. announces the appointment of MALCOLM E. HUNTER as assistant to the president, and WALTER S. COLVIN as director of agricultural sales.

—A—

PAUL A. FRYXELL transferred recently from New Mexico A & M College to the University of Wichita (Kans.) as assistant professor of genetics and botany.

—A—

ROLAND LOISELLE has joined the Cereal Crops Division of the Canada Department of Agriculture as assistant barley breeder at the Ottawa laboratory. He obtained his B.Sc. (Agr.) and M.Sc. degrees from McGill University, and his Ph.D. degree (1955) from the University of Wisconsin.

—A—

R. R. BRUCE, soil physicist at the University of Illinois, is now with the agronomy department at Mississippi State College.

—A—

LEE S. STITH, who was assistant cotton breeder at Texas A & M College, is now at the University of Arizona, Tucson, as assistant plant breeder in charge of the state's sorghum breeding program. He completed work for the Ph.D. degree in plant breeding at Iowa State College in March, 1955.

—A—

LINCOLN TAYLOR has joined the agronomy staff of Virginia Polytechnic Institute as agronomy professor in charge of orchardgrass breeding. A recent grant of $200,000 from the Old Dominion Foundation has enabled VPI to enlarge its orchardgrass breeding project. T. J. SMITH initiated the work which Dr. Taylor is now conducting. Dr. Taylor comes to VPI from the University of Maine.

DARNELL M. WHITT, research liaison representative for the ARS and SCS since April 1, has transferred from the University of Missouri soils department to the University of Illinois soils department at Urbana.

—A—

GEORGE K. MCCUTCHEON, formerly with the research and development department of the New Holland Machine Co., is now at the product planning and programming office of the Ford Motor Co. tractor and implement division, Birmingham, Mich. In this position he maintains liaison between the company and research workers at colleges and experiment stations.

Recent promotions on the University of Wyoming faculty are ALAN A. BEETLE, range management, professor; ROBERT P. PFIEFER, small grains, associate professor; and GEORGE H. BRIDGMON, assistant director, associate professor.

—A—

JOSEPH J. PIERRE, former Illinois State Conservationist, has been promoted to the position of SCS field agronomist for the nine corn belt states. His headquarters will be the University of Illinois agronomy department.

—A—

GEORGE ZIMMERMAN, Rapid City, S. Dak., has been appointed assistant state weed supervisor for western South Dakota.

—A—

ARVID B. HAGEN, Murray county agent at Slayton, Minn., since 1939, has been named supervisor of the new southwest district of the University of Minnesota's Agricultural Extension Service.

—A—

ROBERT D. GROVER, 1949 graduate of Oklahoma A and M College in Agronomy, is the new representative of the U.S. Indian Bureau field service at the sub-agency in Shawnee, Okla.

—A—

JOHN E. BAYLOR, associate extension specialist in farm crops at Rutgers University, began a 2-year leave of absence on Sept. 1 for study toward the Ph.D. degree at the agronomy department of Pennsylvania State University.

—A—

ROBERT W. DUELL has been selected to continue the research program in pastures and forage crops for thoroughbred horses at the New Jersey experiment station which had been conducted by HAROLD W. GAUSMAN. The latter's transfer to the University of Maine was announced in the October issue.

—A—

GENE SPAIN, formerly research assistant in agronomy at the University of Wisconsin, is now an agronomy instructor at Texas Technological College, Lubbock, Tex., teaching a freshman course in agronomy, as well as a course in soils and an advanced course in range management.

—A—

J. J. CURTIS returned Sept. 6 to his position as agricultural technologist at the Northern Utilization Branch, ARS, USDA, Peoria, Ill. He had spent the previous 2 years on leave of absence as agriculturist with the U. S. Operations mission to Afghanistan with headquarters at Lashkari Bazaar.

—A—

LESTER SMITH, Purdue University extension agronomist, has returned to his duties following a long recuperation from serious injuries sustained in an automobile accident last summer. He was extension agronomist in Vermont before transferring to Purdue a year ago.

PERSONNEL SERVICE

Insertions accepted without charge from members of the American Society of Agronomy. For others, the charge is $2.00. Insertions are for 1-time only. Please limit to 100 words.

POSITIONS WANTED

Research and Consulting AGRONOMIST seeks more possibilities to solve difficult problems. University and industrial experience includes: college teaching, laboratory, greenhouse, and field work, improvement of application practices, extension, and advisory activities, technical service to and promotion of sales; last 2 years director of product development of small New Jersey corporation formulating fertilizers and pesticides for horticultural use. Age 34, free to travel, speaking German, Italian, French, Spanish, practical farm work and management, broad training, European degrees: cand. rer. nat., Dipl. Agr., Dr. agr., 1 year study trip through USA in 1951. 11–1

—A—

B.S., M.S. in agriculture 1952, 1953, Ohio State University, majors in agronomy and animal science with graduate fellowship, interested in agronomic service or technical work primarily, also interested in management, production, or sales. Graduate research at Ohio Agr. Exp. Sta. in animal science. Some teaching experience as graduate assistant. Farm background and practical experience. Would welcome inquiries from *any* companies dealing in agricultural products (seed, fertilizer, herbicides, etc.) or active in research. At present on active duty in US Army, to be discharged Feb. 10, 1956. 11–2

AGRONOMY JOURNAL

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AGRONOMY JOURNAL

Volume 47 December 1955 Number 12

Distribution of Atmospheric Moisture in the Microclimate Above a Grass Sod[1]

V. G. Sprague[2]

ATMOSPHERIC moisture commonly thought of in terms of relative humidity is an important climatic factor in agricultural production. The effect of moisture in the environment has been especially emphasized in the analysis of plant disease and hay-making problems. Most of the data reported in studies on moisture content of air over experimental field plots are taken by instruments located at about shoulder height, the standard location generally recommended by the U. S. Weather Bureau. Air temperatures 5 feet or more above ground level may be similar over an area of several square miles but within a few inches of the ground surface (the microclimate), air temperatures (1, 3, 4) may vary widely within even small areas. Atmospheric moisture relationships also vary with the location.

Relative humidity is even more variable than temperature because it involves the amount of moisture in the air in addition to its temperature. By definition, relative humidity is the ratio, in percent, of the vapor pressure of water in a parcel of air to the vapor pressure that it would have if it were saturated. Since this latter varies with temperature, relative humidity may remain constant even when the amount of water in the air increases or decreases. The temperature at which the relative humidity occurs must be considered. A combination of these factors may be expressed as the vapor pressure deficit. Numerically, this is the difference between the vapor pressure of air and that air saturated. This provides a valid comparison of potential evaporation at different locations and at different times irrespective of temperature.

In this study, dewpoint and air temperatures were simultaneously determined at the same places, and relative humidities and vapor pressure deficits were computed for time and location.

Moisture in the air is frequently considered as originating mainly from bodies of water such as lakes, rivers, or the ocean. While water is obtained from these sources, extensive evaporation occurs over land areas from plant foliage and from soils that are normally high in moisture or that are wet from rain.

Since vegetation is one of the primary sources, the moisture content of air was investigated at several heights in the microclimate above a grass sward. Specifically, the objectives of this experiment were: *(1)* to determine seasonal and diurnal variations in dewpoint and air temperatures near a grass sod, and *(2)* to compare them with similar individual and average relationships obtained at the standard height of a U. S. Weather Bureau shelter.

[1] Contribution No. 145 of the U. S. Regional Pasture Research Laboratory, Field Crops Research Branch, A.R.S., U.S.D.A., Pa., in cooperation with the twelve Northeastern States. Received May 20, 1955.

[2] Agronomist, U. S. Regional Pasture Res. Lab.

MATERIALS AND METHODS

Atmospheric moistures and air temperatures reported here were measured at State College, Pa.[3] during 1952, 1953, and 1954 above a good Kentucky bluegrass sod maintained at a height of about 1½ inches. The psychrometric elements were those used by industry for the control of humidities in textile mills and factories. This element, called a "dewcell", consists of a glass-wool, sheath-like wick saturated with lithium chloride that surrounds a resistance thermometer sealed in a metal tube. Wound around the outside of the glass wick are 2 parallel gold wires about a millimeter apart and supplied with about 40 volts a.c. current. The lithium chloride in the wick, being hygroscopic, absorbs moisture from the air and then becomes a conductor of electricity. The current passing through it heats the wick and maintains a temperature in equilibrium with the moisture content of the air. This temperature, measured by the resistance thermometer, is an indication of the amount of moisture in the air. Temperatures of the "dewcell" have been calibrated to indicate the temperature of the dewpoint—the temperature at which the sample of air would be saturated with water.

"Dewcells" were placed at heights of 1½, 3, 6, and 60 inches above the Kentucky bluegrass sod about 100 feet from the Laboratory building. Lead-in cables from these elements and also from resistance thermometers to measure air temperatures were run into the Laboratory building for automatic recording. A time-switch was used to operate the recorder for 15-minute periods at predetermined intervals during each day. These readings from April 1, 1952 to Oct. 31, 1954 were taken at the even hours from 6 a.m. to 6 p.m. E. S. T. and at 3-hour intervals during the night. Only data obtained from April through October will be reported here.

The air and dewpoint temperature records were tabulated and averaged in the usual manner of days, weeks, and months, except that the monthly means refer to the 4- or 5-week periods as used in the solar and sky radiation reports of the U. S. Weather Bureau.

RESULTS AND DISCUSSION

Atmospheric moisture generally decreased with height. Dry air is the result of cold polar air moving into temperate regions, or it may be the result of moist warm air passing over high mountains. The source of water is at ground level, either as a body of water or growing vegetation, and it would be expected that a rapidly increasing moisture gradient would occur even within the microclimate as the water surface is approached.

Dewpoint Temperature

Measurements of dewpoint temperatures throughout the day above a Kentucky bluegrass sod on clear and cloudy midsummer days (figure 1) were determined at 4 heights from 1½ to 60 inches. These data indicate that: *(1)* the moisture content of the air is greatest near ground level; *(2)* the most rapid changes in dewpoint temperatures are in the 6-inch zone immediately above ground; *(3)* the vertical gradients of dewpoint temperatures are more pro-

[3] 40° 48′ N. latitude; 77° 52′ W. longitude; 1,195 ft. altitude above mean sea level.

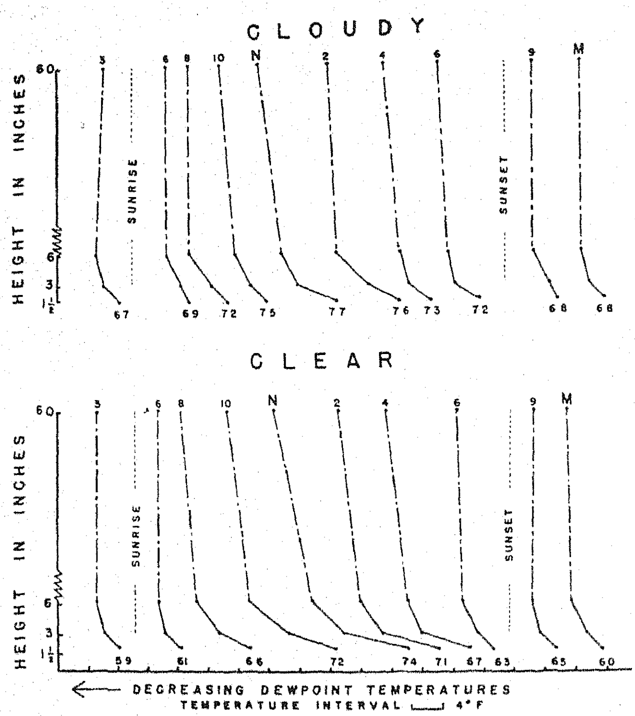

FIG. 1.—Characteristic vertical variation of average dewpoint temperatures during 24 hours above a Kentucky bluegrass sod: 7 cloudy days (top), 12 clear days (bottom) during July 1952. (Approximate sunrise 4:45 a.m., sunset 7:30 p.m. E. S. T.).

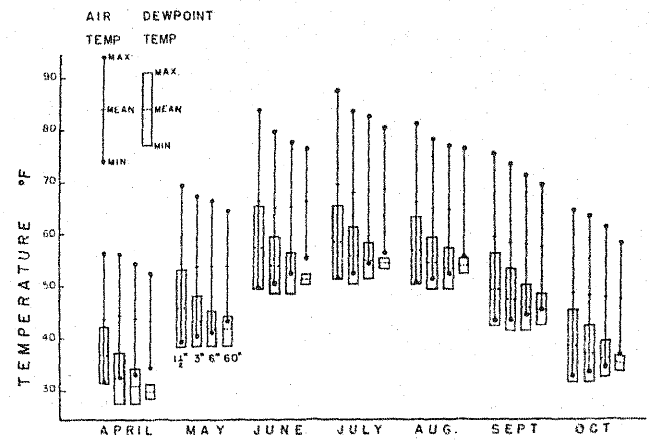

FIG. 2.—Atmospheric temperature and moisture characteristics at 4 heights (1½, 3, 6, and 60 inches) above a Kentucky bluegrass sod during April to October inclusive at State College, Pa. These data are monthly averages of daily determinations, 1952–54 inclusive.

nounced on clear days than cloudy days; and *(4)* the largest gradients occur between 10 a.m. and 2 p.m., coincident with the time of greatest radiation from the sun.

Radiant energy, during the day, increases temperatures of soil and plant surfaces, and this increases the amount of water evaporated from these surfaces and that transpired by plants. The air also is heated and an unstable condition exists. The warm air tends to rise and carries the moisture with it. This is particularly evident at the 1½ to 3-inch heights and to a lesser extent at the 6-inch height and above. On cloudy days, dewpoints are generally those that have moved in from the humid Gulf States, whereas the air masses present on clear days have come from the polar region and contain lesser amounts of water. In late afternoon, temperature and moisture gradients decrease and conditions become stable. During the night, temperature conditions remain stable and a gradual decrease in the dewpoint is observed at increasing heights. Cooling of plant surfaces by out-going radiation at night, to below the dewpoint temperatures, removes water from the air by condensation on the plant surfaces as dew.

Daily readings of the dewpoints at maximum and minimum air temperatures were obtained during the months of April through October for the period 1952–54 inclusive. These are summarized as monthly averages for the heights of 1½, 3, 6, and 60 inches above the ground over a Kentucky bluegrass sod (figure 2). It is evident for all months that at the time of daily maximum air temperatures dewpoint temperatures also are highest near ground level and become progressively lower with increasing height up to 60 inches. At the time of daily minimum air temperatures, dewpoint temperatures are lower and differences between dewpoints at the different heights (figure 2) are smaller than at the time of maximum temperatures.

Largest average daily ranges in dewpoint temperatures occur near ground level and the smallest ranges occur at the 60-inch height. At this height, at the time of maximum air temperatures, dewpoint temperatures averaged lower for each month during the growing season (April–October) than at locations closer to the ground. At the time of minimum temperatures, however, dewpoints averaged higher with increasing distance above the ground. Lower dewpoint temperature near ground level may have been partially caused by the removal of moisture from the air by condensation on plant leaves whose surfaces were first to cool below the dewpoint. Air temperatures determined at several heights above the ground and over a grass sod followed the previously reported (3, 4) pattern of higher daily maximum temperatures and lower daily minimum temperatures near the ground level than at the 60-inch height (figure 2).

Diurnal changes in atmospheric moisture on clear and cloudy mid-summer days differ with height. Air temperatures and the amounts of water in the air (indicated by the dewpoints), as well as their interrelationships (vapor pressure deficits and relative humidities), vary with the time of day and also with the height above ground level. Air temperatures on both clear and cloudy days usually increase from sunrise to mid-day; they then begin to decrease and reach their minimum just before sunrise.

Dewpoint temperatures 1½ inches above ground level follow a pattern similar to that shown by air temperatures. Sixty inches above ground, the diurnal variation in dewpoint temperatures is small and the moisture in the air is generally greater on cloudy days than on clear days (figure 3). These relationships follow from the frequent presence of a humid air mass that originated in warm areas with extensive vegetative ground cover or free water. The lower moisture content of the air on clear days usually results from the influx of a mass of polar air containing less moisture.

On clear days from sunrise to sunet, dewpoint temperatures near ground level follow a pattern similar to that of the air temperature. The inversion of air temperatures which occurs during the night is not accompanied, however, by an inversion of dewpoint temperatures. During the daytime, radiant energy from the sun evaporates water from

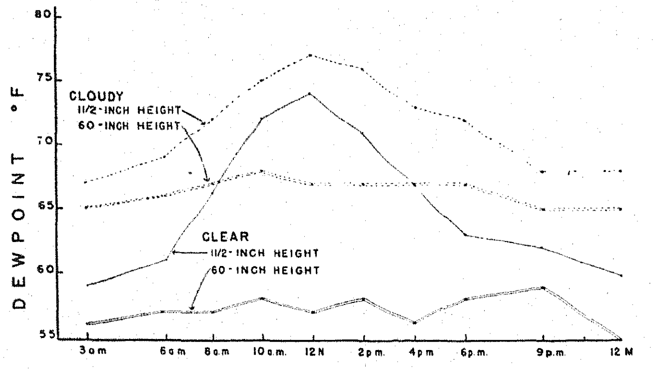

FIG. 3.—Diurnal changes in dewpoint temperatures at 2 heights above ground over a bluegrass sod on clear days (average of 12) and on cloudy days (average of 7), July 1952. (Approximate sunrise 4:45 a.m., sunset 7:30 p.m. E. S. T.).

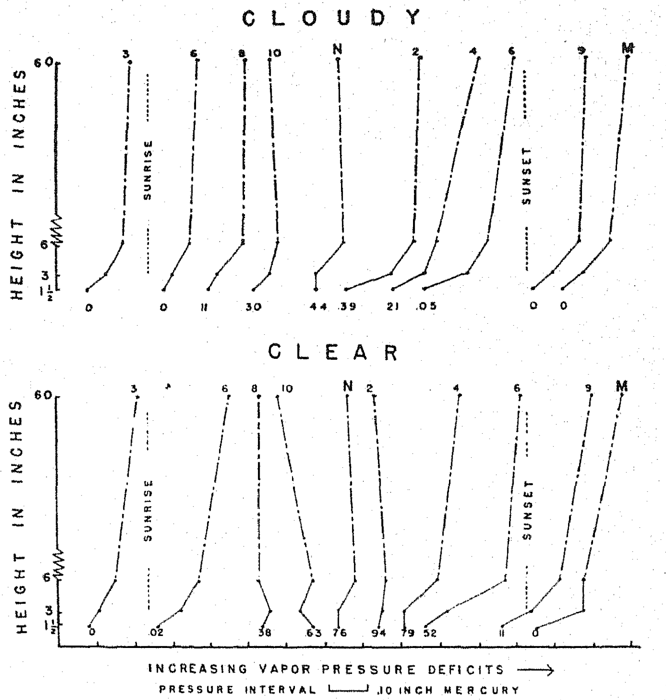

FIG. 4.—Characteristic vertical variation of average vapor pressure deficits, to 2 decimals, during 24 hours above a Kentucky bluegrass sod; 7 cloudy days (top), 12 clear days (bottom), during July 1952. (Approximate sunrise 4:45 a.m., sunset 7:30 p.m. E. S. T.).

the ground surface and increases the transpiration rates of plants. Air warmed during the daytime rises and carries the water vapor with it. In the afternoon, air nearest the ground cools first, becomes heavier and tends to remain at ground level. The temperature of this cooler air frequently reaches the saturation point and dew is formed, with some loss of atmospheric water. The result is a decrease of dewpoint temperatures at the 1½-inch height. Except during a fog or prolonged rain, air temperatures at the 60-inch height seldom reach the dewpoint.

Vapor Pressure Deficit

Moisture relationships of the air in this study are discussed primarily on the basis of vapor pressure deficit. This is the difference between the saturation vapor pressure at the observed air and dewpoint temperatures. A range of such vapor pressures from 20 to 140° F. are reported in the U. S. Weather Bureau tables (2).

Vapor pressure deficits provide an indication of the evaporation potential of a water surface, and for practical purposes, it may be assumed that the foliage of most plants acts as a water surface. The vapor pressure of this surface is determined by the temperature of the foliage, and the water loss will be proportional to the difference between the vapor pressure at the temperature of the leaf and the vapor pressure of the surrounding air.

The diurnal sequence of the gradients of vapor pressure deficits with height (figure 4) indicates that, on clear days soon after sunrise, the deficits nearest the ground are first to increase in response to rapid warming. At noon, differences between heights decrease and the vapor pressure deficits are similar at 1½ inches and 60 inches above the ground. In the afternoon, vapor pressure deficits begin to decrease first near ground level in response to cooling by terrestrial radiation. The differences between heights become greatest near sunset. On cloudy days, a similar pattern prevails but the effects, due to height are less marked. The pattern of hourly changes in vapor pressure deficits near ground level and at 60 inches (figure 5) clearly indicates that more rapid changes and greater extremes occur near ground level on both clear and partly cloudy days.

The increase of vapor pressure deficits from April through July is associated with the season increase in daily maximum air temperatures; the decrease in vapor pressure deficits from August through October is similarly associated

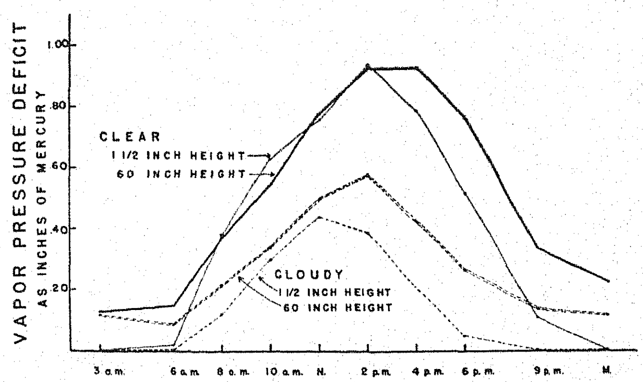

FIG. 5.—Diurnal changes in average vapor pressure deficits at two heights above a Kentucky bluegrass sod during 12 clear days and 8 cloudy days in July 1952. (Approximate sunrise 4:45 a.m., sunset 7:30 p.m. E. S. T.).

with the decrease in air temperatures. At daily minimum air temperatures the vapor pressure deficits are much smaller and approach zero.

Relative Humidity

Relative humidity has frequently been used in general discussions of atmospheric moisture, probably following the development of the rather simple and inexpensive instruments which can be read directly as relative humidity. Without evaluating temperature effects, relative humidity may be misleading as an indication of the rate of water loss. For example, quite different vapor pressure deficits may ocucr when the relative humidities are the same (table 1). A relative humidity of 49% occurred under three dif-

Table 1.—Variation in vapor pressure deficits at the same relative humidities.*

Date and location above KB	Relative humidity, %	Vapor pressure deficit, e	Air temperature °F.	Dewpoint temperature °F.
	%	e†		
May—5-ft. height	49	0.37	70	50
June—6-inch height	49	0.57	83	62
July—1½-inch height	49	0.79	93	71

* These data are 3-year averages of observations taken at the time of daily maximum temperatures.

ferent conditions above a grass sod even though the vapor pressure deficit (rate of evaporation) doubled between the 60-inch height in May and the 1½-inch height in July.

Because atmospheric moisture conditions are frequently expressed as relative humidities, the data are briefly reported as such. Fundamentally, relative humidity involves both dewpoint and air temperatures, expressed in combination as the calculated percentage saturation of the air at any one temperature.

The rates of change of relative humidity associated with height are similar at all heights during the daylight hours, but after sunset, changes become more marked and relative humidity increases most rapidly near ground level. Diurnal variations in relative humidities indicate appreciable differences between heights on both clear and cloudy days (figure 6). Relative humidities were higher at the 1½-inch height than above, and at this height 100% relative humidity usually was reached before midnight and remained until after sunrise.

In the macroclimate, the relative humidity seldom reaches 100% except during a prolonged rain or a foggy period; during clear nights, and even during showers, it remains between 75 and 95%. Where it is known that certain relative humidities favor development of individual plant diseases, observations taken only at the standard height may be misleading, and particularly if these conditions are assumed to be the same as those in the climate surrounding the plants.

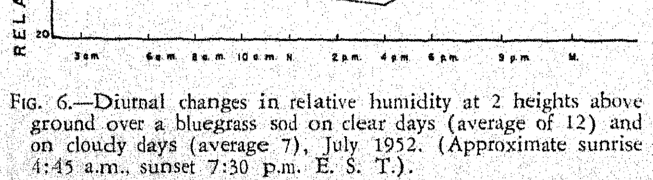

Fig. 6.—Diurnal changes in relative humidity at 2 heights above ground over a bluegrass sod on clear days (average of 12) and on cloudy days (average 7), July 1952. (Approximate sunrise 4:45 a.m., sunset 7:30 p.m. E. S. T.).

A general comparison of atmospheric moisture conditions during the growing season for the months of April through October is presented as vapor pressure deficits and as relative humidities for different heights above ground level (table 2). Increasing vapor pressure deficits are associated with increasing daylengths from April to July. During the mid- and late-summer months and at the times of daily maximum temperatures, vapor pressure deficits are generally greater near ground level than at the 60-inch height, but during late spring and early summer this is less evident. In July the rate of evaporation at the maximum temperature is about three times greater than in April, but in May and October it is only about one-third greater than in April.

Data in table 2 indicate that at the 1½-inch height, vapor pressure deficits are more than 50 times greater at the time of maximum temperature than at the time of the minimum temperature; at the 3-inch height they are only 15 to 20 times greater. At the 6 and 60-inch heights this relationship is further reduced and vapor pressure deficits are 5 to 10 times greater at the maximum temperature than at the minimum.

Relative humidities are lowest during maximum temperatures for all months and at all heights and are highest at the times of minimum temperatures. It is also evident that relative humidities are higher near ground level at both the maximum and minimum air temperatures and decrease with increasing height above the ground. The usual diurnal range in relative humidity is about 50%, with the extreme difference between monthly averages only about 15%.

In comparisons of atmospheric moisture in the microclimate with those at 60 inches, it is evident that wide variations in vapor pressure deficits and relative humidities occur with height. Both the 1½-inch and 3-inch heights are definitely in the microclimatic layer, whereas the 6-inch height appears to approach the upper limit of the microclimatic layer and becomes similar to the 60-inch height.

SUMMARY

Atmospheric moisture and temperature were determined from April through October 1952–54 at heights of 1½, 3, 6, and 60 inches above a grass sod at State College, Pa. Measurements were taken at the even hours from 6 a.m. to 6 p.m. and at 3-hour intervals during the night.

The average moisture content of the air, for each month, decreased progressively with height. Near ground level, the moisture content of the air was greatest at noon or soon thereafter and was consistently greater during the day than during the night. At the standard 60-inch height the variation during the day was small. On cloudy days more water was in the air than on clear days.

Vapor pressure deficits calculated from mean daily maximum air temperatures and dewpoint temperatures, observed at the same time, indicate progressive increases in the vapor pressure deficits from April through July, and also from the 1½-inch to the 60-inch height. Progressive decreases followed from August through October. Greater vapor pressure deficits occurred with increasing heights above the ground during both the mean daily maximum and minimum air temperatures.

Relative humidities were greater near ground level than above during both maximum and minimum air temperatures. The largest differences between the relative humidity

Table 2.—Atmospheric moisture at 4 different heights above ground level over a grass sod. Data presented are averages of daily observations, 1952–54 inclusive.

Month	1½-inch		3-inch		6-inch		60-inch	
	VPD e	RH %	VPD e	RH %	VPD e	RH %	VPD e	RH %
	At maximum temperatures							
April	0.22	60	0.28	50	0.27	48	0.26	46
May	0.37	58	0.39	52	0.41	48	0.37	49
June	0.61	56	0.59	52	0.57	49	0.61	44
July	0.79	49	0.70	48	0.73	45	0.71	43
August	0.57	55	0.55	53	0.55	49	0.56	49
September	0.50	53	0.49	51	0.48	49	0.45	48
October	0.36	51	0.37	47	0.36	45	0.33	45
Average	0.49	55	0.48	50	0.48	48	0.47	46
	At minimum temperatures							
April	0	100	0.04	82	0.05	79	0.05	79
May	0.01	97	0.02	93	0.04	89	0.06	83
June	0	100	0.03	93	0.07	84	0.09	84
July	0	100	0.04	93	0.05	90	0.06	90
August	0	100	0.03	93	0.05	90	0.05	90
September	0.01	96	0.03	93	0.04	89	0.04	89
October	0.01	96	0.02	93	0.02	93	0.03	89
Average	0.004	99	0.03	91	0.05	88	0.05	86

in the microclimate near the grass sod and in the macroclimate 60 inches above the grass occurred during daily maximum air temperatures. Relative humidities were highest at the daily minimum air temperatures.

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The Influence of Photoperiod and Temperature on Growth, Flowering, and Seed Production of Dallisgrass, *Paspalum dilatatum* Poir[1]

W. E. Knight[2]

DALLISGRASS, *Paspalum dilatatum* Poir. is one of the most valuable pasture plants in the cotton belt states (2, 6). It is adapted to a wide range of growing conditions and produces herbage of high quality. Maximum utilization of this crop has been retarded by the high cost of imported seed and the poor quality of domestic seed. Cytological studies conducted by Burton (3) indicate that the low percent of seed set is largely due to chromosomal aberrations. Experiments in Louisiana (6) show that Dallisgrass seed heads often contain a large percentage of light or empty florets which tend to remain attached to the seed heads. Bennett (1) found that the embryo of Dallisgrass was mature in 14 to 18 days after pollination and recommended earlier harvest to improve quality of seed. Marchbanks[3] found that Dallisgrass harvested at 14, 18, and 28 days after flowering had high viability. Drying tests on this seed indicated that Dallisgrass seed with a moisture content below 35% can be dried at temperatures up to 140° F. without reducing the viability. Lovvorn (5) found that Dallisgrass produced more top growth under a temperature of 80 to 90° F. and short day than under a temperature of 60 to 70° F. and the same day length. Three seed sources and vegetative material from two plants of Dallisgrass were studied by Knight and Bennett (4), in 1951–52,

[1] Cooperative investigations at State College, Miss., of the Field Crops Research Branch, A.R.S., U.S.D.A., and the Mississippi Agr. Exp. Sta. Approved for publication as Journal Article No. 504, Mississippi Agr. Exp. Sta. Received July 1, 1955.

[2] Research Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A.

[3] Marchbanks, W. W. Limits of viability of roughpea and Dallisgrass seed. Embryology of *Lathyrus hirsutus* L. Ph.D. thesis, Mississippi State College Library, 1953.

Table 1.—Flowering and seed production of two strains of Dallisgrass grown in the greenhouse continuously with a night temperature of 65 to 70° F., 1952–53.

Characteristic	Photoperiod and strain				Photoperiod means		Strain means		Coefficients of variation
	14 hours		16 hours						
	B230	S430	B230	S430	14	16	B230	S430	
Days to flowering	80	77	92	90	78.5**	91.0	86.0**	83.5	2.6%
Number of panicles	20	22	16	19	21.0**	17.5	18.0	20.5**	11.3%
Total wt. of seed, g.	8.9	9.1	7.2	8.2	9.0**	7.7	8.1	8.7	9.7%
Shattered seed, g.	5.1	5.3	3.8	4.8	5.2	4.3	4.5	5.1	15.6%
Non-shattered seed, g.	3.8	3.8	3.4	3.4	3.8	3.4	3.6	3.6	11.5%
% Caryopses in shattered seed	84.0	61.8	72.8	54.7	72.9**	63.8	78.4**	58.3	12.5%
% Caryopses in non-shattered seed	1.8	1.2	1.3	1.0	1.5	1.2	1.6	1.1	——
Racemes per panicle	5	5	5	5	5	5	5	5	12%

** Significant at the 1% level.

in a preliminary investigation of photoperiodic response. Best seed production of Dallisgrass resulted when 14 and 16 hour daylengths were used in combination with high night temperature. Night temperatures below 55° F. inhibited seed head formation. The results of these experiments indicated that prior treatment of vegetative plant material might mask photoperiodic response and make interpretation of results from vegetative materials difficult.

It was the purpose of the investigation reported here to obtain additional basic information on the response of Dallisgrass to photoperiod and temperature with particular emphasis on flowering and seed production.

MATERIALS AND METHODS

The plant material used in the 1952–53 experiments was from two Louisiana seed sources, since previous results suggested the use of seedling material of known origin. In the fall of 1952, plants from two seed sources were transplanted into ½-gallon glazed pots containing a uniform potting mixture of 4 parts of soil to 1 part of sheep manure. Six replications, containing three plants each, were grown in two greenhouses. The temperature in one greenhouse was kept at 65 to 75° F. at night and between 70 to 80° F. during the day. The plants were placed under 8, 11–12 (normal), 12, 14, and 16 hour photoperiods when potted. The second greenhouse provided less accurate control of temperature, with night temperatures ranging from 45 to 55° F. and day temperatures ranging between 70 to 80° F. Plants were grown in this greenhouse for 10 weeks under normal day and then moved to the high temperature house and placed under 8, 11–12 (normal), 12, 14, and 16 hour photoperiods.

Records were taken on the date of emergence of the first inflorescence, number of panicles, weight of seed, percentage florets having caryopses, height and number of culms. Height measurements and culm counts were made when the plants were 6, 8, and 10 weeks of age. Seed were harvested by bagging individual panicles to catch the seed which shattered. All of the florets remaining on the racemes were hand stripped when the heads were mature.

RESULTS AND DISCUSSION

Dallisgrass responded similarly to photoperiod and temperature in 1951–52 and in 1952–53; hence, only the data from the latter experiment are given here.

Data on seed production of Dallisgrass when grown under a 14- and 16-hour day with a 60 to 70° F. night temperature are given in table 1. Data for an 8-hour, normal, and a 12-hour day are not given since Dallisgrass failed to produce seed under these short day lengths.

Dallisgrass grown under a continuous night temperature of 65 to 70° F. flowered earlier under the 14-hour photoperiod than under the 16-hour treatment (table 1). The 14-hour day also produced a significantly higher number of panicles, a higher total weight of seed and a higher percentage of seed with caryopses. Strain S430 was earlier in flowering than B230 and produced a higher number of panicles. The total weight of the seed produced by the two strains did not differ significantly, yet B230 produced a much higher percentage of florets with caryopses.

The response of Dallisgrass grown with a night temperature of 45 to 55° F. for 10 weeks and transferred

Table 2.—Flowering and seed production of 2 strains of Dallisgrass rotated at 10 weeks of age from a night temperature of 45 to 55° F. and normal day to a night temperature of 65 to 70° F. and long day, 1952–53.

Characteristic	Photoperiod and strain				Photoperiod means		Strain means		Coefficients of variation
	14 hours		16 hours						
	B230	S430	B230	S430	14	16	B230	S430	
Days to flowering	116	115	124	111	115.5	117.5	120	113	7.9%
Number of panicles	16	15	11	14	15.5**	12.5	13.5	14.5*	8.5%
Total wt. of seed, g.	6.9	7.8	5.8	6.4	7.4**	6.1	6.4	7.1**	8.3%
Shattered seed, g.	3.1	4.0	2.8	3.4	3.6	3.1	3.0	3.7**	17.0%
Non-shattered seed, g.	3.8	3.8	3.0	3.0	3.8**	3.0	3.4	3.4	15.3%
% Caryopses in shattered seed	46.8	56.3	29.8	23.0	51.6**	26.4	38.3	39.7	32.1%
% Caryopses in non-shattered seed	1.3	1.5	0.7	0.0	1.4	0.35	1.0	0.75	——

* Significant at the 5% level.
** Significant at the 1% level.

to a night temperature of 65 to 70° F. is shown in table 2. The same pattern of response for strains occurred under this treatment as under the continuous high night temperature treatment with the exception of percent caryopses in the shattered seed. The two strains were not significantly different in percent caryopses, and the percentage caryopses in the shattered florets was much lower than under the continuous high temperature treatment. A much lower percentage florets with caryopses was found for the 14-hour day length following a period of low night temperatures. In 1951–52, the series of plants grown under a continuous night temperature of 45 to 55° F. and a photoperiod of 14 hours failed to produce seed heads.

The effect of photoperiod on growth for plants 6, 8, and 10 weeks of age is shown in tables 3 and 4. Strains did not differ significantly in height or in number of culms produced. Photoperiods differed significantly but a significant interaction of age × photoperiod limits comparisons to within age groups. The 16-hour photoperiod retarded both culm formation and height during the first 6 weeks of growth. Figure 1 shows the comparative growth and stage of maturity of Dallisgrass at 10 weeks of age grown with high night temperature and under 5 photoperiods.

Table 3.—Effect of photoperiod on the number of culms produced by Dallisgrass grown in the greenhouse with a night temperature of 65 to 75° F., 1952–53.

Strain	Age of plants weeks	Length of photoperiod					Means
		8	N	12	14	16	
B230	6	5.0	7.7	9.5	9.5	8.0	7.9
	8	16.0	20.2	24.5	23.2	16.3	20.0
	10	44.0	32.5	28.8	24.3	17.3	29.4
	Means	21.7	20.1	20.9	19.0	13.9	19.1
S430	6	—	9.2	10.2	10.0	5.0	8.6
	8	—	25.2	25.7	21.7	13.8	21.6
	10	—	37.2	30.2	22.3	15.0	26.2
	Means	—	23.9	22.0	18.0	11.3	18.8

L.S.D. 0.05 = 0.87 to compare photoperiod means within each age.
L.S.D. 0.01 = 1.17
C.V. = 5%

Table 4.—Effect of photoperiod on the height in inches of Dallisgrass grown in the greenhouse with a night temperature of 65 to 70° F., 1952–53.

Strain	Age of plants weeks	Length of photoperiod					Means
		8	N	12	14	16	
B230	6	5.0	8.8	12.7	14.3	12.5	10.7
	8	7.0	15.0	20.8	24.3	24.0	18.2
	10	13.3	24.5	31.2	36.8	39.7	29.1
	Means	8.4	16.1	21.6	25.1	25.4	19.3
S430	6	—	11.3	14.0	16.0	14.3	13.9
	8	—	16.8	21.5	25.3	25.7	22.3
	10	—	23.3	29.0	37.8	39.2	32.3
	Means	—	17.1	21.5	26.4	26.4	22.8

L.S.D. 0.05 = 1.40 to compare photoperiod means within each age.
L.S.D. 0.01 = 1.87
C.V. = 13%

The effect of two temperature treatments on the growth of Dallisgrass is shown in table 5. Strain S430 was superior in growth to B230 as shown by number of culms and height, and was also earlier in maturity than B230.

Plants grown with a night temperature of 65 to 70° F. were taller and produced more culms than the plants grown with low night temperature. This is in agreement with the work reported by Lovvorn (5). There was a significant interaction between age and temperature for height measurements which restricts comparisons to within age groups. Figure 2 shows plants at 10 weeks of age grown under the 2 temperature treatments and a normal day. There was a decided similarity between plants grown under a normal day and a low temperature and plants grown under an 8-hour day and a high temperature (figures 1 and 2).

A high night temperature and a 14-hour photoperiod appear to provide the most desirable environment for greenhouse production of Dallisgrass. There appears to be no advantage from the standpoint of seed production in grow-

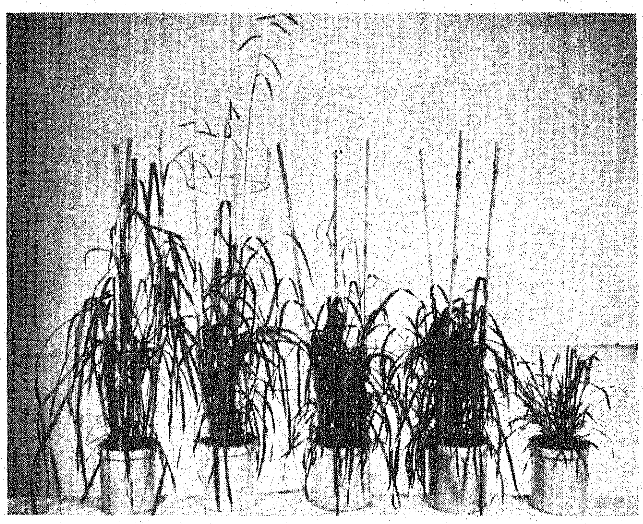

FIG. 1.—Dallisgrass grown continuously under night temperatures of 65 to 70° F. Photoperiods: l. to r.—16, 14, 12, N, and 8 hours.

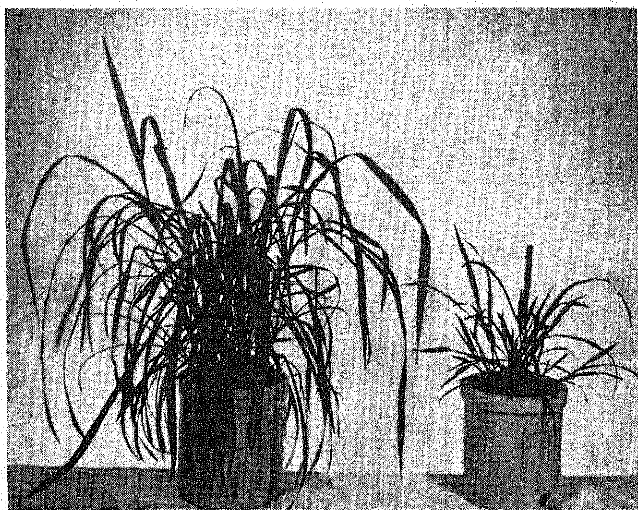

FIG. 2.—Dallisgrass grown under normal day and with night temperatures of (left) 65 to 70° F., and (right) 45 to 55° F.

Table 5.—Number of culms and height of Dallisgrass under a normal day and two temperature treatments, 1952–53.

Strain	Age of plants and temperature treatment*									Temperature means		Strain means	C.V.
	6-weeks			8-weeks			10-weeks						
	T_1	T_2	Mean	T_1	T_2	Mean	T_1	T_2	Mean	T_1	T_2		
							Number of culms						
B230	7.7	3.8	5.8	20.2	12.3	16.3	32.5	24.2	28.4	20.1	13.4	16.8	17%
S430	9.2	4.7	7.0	25.2	13.3	19.3	37.2	28.0	32.6	23.9	15.3	19.6**	
										22.0**	14.4		
							Height (inches)						
B230	8.8	4.5	6.7	15.0	5.7	10.4	24.5	15.3	19.9	16.1	8.5	12.3	10%
S430	11.3	5.5	8.4	16.8	6.5	11.7	23.3	17.0	20.2	17.1	9.7	13.4**	
	10.1	5.0	7.6	15.9	6.1	11.1	23.9	16.2	20.1	16.6	9.1		

L.S.D. 0.05 = 0.60 to compare temperature means for height within each age.
0.01 = 0.80

* Temperature treatments: T_1 = Night temperature 65 to 70° F.
T_2 = Night temperature 45 to 55° F.

** Significant at the 1% level.

ing Dallisgrass under low temperature during the formative period of growth.

Because of early shattering of Dallisgrass seed in 1951–52, seed was harvested by shaking the heads over a pan. Seed heads were bagged in 1952–53 to avoid the frequent harvests of seed. Representative heads from strain B230 were harvested at varying stages of maturity to determine the relationship of seed shattering to stage of maturity (table 6). These data suggest the desirability of early harvest of Dallisgrass seed with a shaker or shaker-suction harvester. Seed quality should be greatly increased by such a harvest method. The problem of separating empty florets from good seed would be eliminated to a great extent since the empty florets tend to remain attached to the raceme until maturity is advanced (table 6). Bennett (1) proposed earlier harvesting as a means of improving quality after determining that the embryo of Dallisgass is mature in 14 to 18 days after pollination. Early harvest will require special attention to seed drying. However, recent work by Marchbanks[3] indicates that Dallisgrass seed with a moisture content below 35% can be dried at temperatures up to 140° F. without reducing the viability.

The ease with which Dallisgrass seed shatter has been noted by other workers[4] (6). Owen (6) cites correspondence which indicates that Dallisgrass seed have been harvested in Australia by shaking the panicles over pans. This may partially explain the higher quality of imported seed as compared to the usually poor quality of domestic seed harvested by combining directly or combining material which has been mowed and windrowed.

Table 6.—Shattering of Dallisgrass seed as related to stage of maturity.

Plant characteristic measured	Stage of maturity when harvested		
	Stem and glumes green	Stem and glumes brown but not dry	Stem and glumes dry
Total number of florest	450	328	475
Number of florest shattered	150	173	243
Percent of shattered florest with caryopses	97	81	67
Number of shattered florets containing caryopses	146	140	163
Number of non-shattered florets	300	155	232
Percent of non-shattered florets containing caryopses	14	5	5
Number of non-shattered florets containing caryopses	42	8	12
Percent of total florets containing caryopses that had shattered when harvested	78	95	93
Percent of total florets containing caryopses	42	45	37

SUMMARY

Two selections of Dallisgrass from Louisiana were grown in the greenhouse in 1951–52 and 1952–53 to determine flowering and seed production response to photoperiod and temperature treatments.

Dallisgrass was grown in one greenhouse under a night temperature of 65 to 70° F. and between 45 to 55° F. in another greenhouse. Day temperatures ranged from 70 to 80° F. in both houses.

The general response of Dallisgrass to photoperiod and temperature was the same in 1951–52 and in 1952–53. Dallisgrass failed to produce seed heads when grown under an 8-hour and a normal day. Seed head production under a 12-hour day was erratic and flowering was incomplete. A high night temperature and a 14-hour photoperiod appear to provide the most desirable environment for greenhouse production of Dallisgrass. There appears to be no advantage from the standpoint of seed production in growing Dallisgrass under low temperature during the formative period of growth. Low night temperatures inhibited seed head formation in Dallisgrass under long day.

A modified method of harvest for Dallisgrass seed utilizing a shaker or shaker-suction harvester is suggested by

[4] Marchbanks, *op. cit.*

the results of these experiments. The quality of seed harvested in such a manner should be superior to that of combined seed.

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Effects of Nitrogen Fertilization and Rate and Method of Seeding on Grass Seed Yields in Pennsylvania[1]

Roderic E. Buller[2], J. S. Bubar[2], H. R. Fortmann,[3] and H. L. Carnahan[4]

SEED production of improved forage grasses has developed into a highly specialized enterprise in the United States. Progress has been made towards fulfilling the seed requirements of farmers in the northeastern United States by producing seed of improved varieties in western states. However, the production and maintenance of breeder seed of new varieties will continue to be a responsibility of the originating station.

The objectives of this study were: *(1)* to determine the cultural practices which stimulate maximum seed production of orchardgrass, smooth bromegrass, timothy and reed canarygrass; *(2)* to determine the effects of the various cultural treatments on the plant characteristics which are components of seed yield. Results and conclusions pertaining to this last objective will be presented in another paper.

REVIEW OF LITERATURE

Although investigations on grass seed production have been conducted in many different geographical regions of the United States, very little information has been accumulated in the Northeast. Nitrogen is generally considered the key element in grass seed production (1, 3, 10, 11, 14, 15) with a lesser emphasis on phosphorus and potash. Metcalfe (9) in Iowa, and Churchill (2) in Michigan have shown that approximately 80 pounds of nitrogen per acre on broadcast stands was the most practical application for increasing seed yields of smooth bromegrass. Spencer (14) in Kentucky found that approximately 64 pounds of nitrogen per acre doubled the seed yields over the check of both Kentucky 31 tall fescue and commercial orchardgrass. Early spring applications were best on orchardgrass, whereas, spring and fall applications were equally effective on fescue. Knowles and Cooke (7) found fall applications superior to spring applications on well-established smooth bromegrass. Evans (4) in England found that ammonium sulfate increased seed yields of orchardgrass with little benefit resulting from applications higher than 4 cwt. per acre. Timothy seed yields were increased by nitrogen applications only in the second year.

Grasses in rows generally yield more seed per acre than broadcast seedings; however, in some studies orchardgrass was found to produce higher yields on broadcast seedings (2, 5, 6, 14). Stanford[5] at the Pennsylvania Agricultural Experiment Station concluded that cultivated row seed production was superior to solid stand for tall fescue, orchardgrass, and common tall oatgrass. Tualatin tall oatgrass was the only grass that produced more seed in solid stands. Schwanbon and Froier (12) reviewed seed production studies on timothy and orchardgrass conducted by Scandinavian, German, and Dutch investigators. With timothy they reported evidence which favored 14- to 20-inch drill spacing while 18- to 24-inch drill spacings were preferred for orchardgrass with a seeding rate of 7 pounds per acre.

Sears (13) recommended seeding rates of 6 to 8 pounds per acre for broadcast seeding of orchardgrass for seed production in New Zealand. Spencer (14) found that seed yields of Kentucky 31 fescue and orchardgrass decreased as seeding rates increased from 3 pounds to 7 and 15 pounds per acre in broadcast stands. Knowles, *et al.* (7) recommended a seeding rate of 6 to 8 pounds per acre for bromegrass in western Canada.

MATERIALS AND METHODS

The experiment was located on the Pennsylvania Agricultural Experiment Station Farm, University Park, Pa. The soil type of the experimental site has been classified as Hublersburg silt loam which is a deep soil from low to medium fertility with a pH of approximately 6.7. Prior to seeding, the field received 600 pounds of 0–20–0 per acre; 300 pounds of 0–20–20 per acre plus 300 pounds of ammonium sulfate per acre. Seeding was done on May 1 and 2, 1951. A top-dressing of 300 pounds of 0–20–20 per acre was made on April 11, 1952, and again on April 23, 1953.

The four perennial grasses included in this study were Achenbach smooth bromegrass, Climax timothy, common orchardgrass and common reed canarygrass. The experimental factors consisted of methods of seeding (36-inch rows vs. broadcast), 7 nitrogen

[1] Contribution from the Department of Agronomy, Pennsylvania State University, University Park, Pa. Authorized for publication on May 10, 1955 as paper No. 1979 in the Journal Series of the Pennsylvania Agr. Exp. Sta. Received July 13, 1955. More extensive data and details on the experiments are contained in the Ph.D. and M.S. dissertations, of the first and second authors, in the library of the Pennsylvania State University, University Park, Pa.

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[3] Associate Professor of Agronomy, Pennsylvania State University.

[4] Research Agronomist, U. S. Regional Pasture Research Laboratory, University Park, Pa.

[5] Stanford, J. P. Adaptation of herbaceous materials for highway slope control. Ph.D. dissertation. The Pennsylvania State University. 1951.

treatments involving rates and times of application and rates of seeding. Split nitrogen treatments involved equal applications in spring and fall. The rates of seeding for each species and method of seeding are listed below:

Grass	Pounds of pure live seed per acre	
	High rate	Low rate
Bromegrass and reed canarygrass		
Broadcast	8	4
Row	4	2
Orchardgrass and timothy		
Broadcast	6	3
Row	3	1½

Nitrogen in the form of ammonium sulfate was applied Sept. 22, 1951; March 29, 1952; Oct. 16, 1952; and April 3, 1953.

A split, split plot design with these replications provided for all possible combinations of the above treatments. Methods of seeding constituted the main-plots, nitrogen the seven sub-plots and rates of seeding the two sub-sub-plots for each species.

The dimensions of the individual broadcast plots were 5 by 20 feet and those of the row plots were 3 by 20 feet. All plots were seeded by hand and cultipacked. Row plots were cultivated when necessary. Borders were trimmed from the plots before harvesting the seed heads. The heads were dried in a forced air dryer. Threshing was done with a small hammer mill. Straw was removed by hand and the seed cleaned in a small "Clipper" cleaner. Seed yields were determined as pounds of clean seed per acre.

RESULTS AND DISCUSSION

Grass seed production obtained in this study was highly satisfactory compared with yields obtained in other humid regions. Table 1 illustrates that average seed yields of reed canarygrass, orchardgrass, and timothy were much higher in 1953 than in 1952. A slight reduction was observed for smooth bromegrass.

The combined average seed yields for 1952 and 1953 for each grass species are presented in tables 2, 3, 4, and 5.

The analyses of variance revealed that many of the treatment interactions were significant as well as some of the interactions involving years. These interactions are explained in terms of seed yield responses where they have been found to have a strong influence on interpretation of results and formation of conclusions.

Reed canarygrass.—Average seed yield was very low the first harvest year. The low yield of 20 pounds per acre was primarily due to lack of seed head production. Responses to all treatments were much greater in the second year and similar to those obtained in the first harvest year. Rows yielded significantly more seed than broadcast stands. All 100 pound per acre nitrogen treatments yielded significantly more seed than the check or 50 pound per acre treatments. There was a yield advantage in splitting the higher rate although the split application was not significantly better than the same amount applied in the spring. The lower seeding rate yielded significantly more seed than the higher rate. There was no lodging in any of the plots. The absence of lodging and the large seed increase that occurred with 100 pounds of nitrogen per acre indicate that higher rates of nitrogen might result in further yield increases.

Smooth bromegrass.—An average of 200 pounds more seed per acre was produced in rows than in broadcast stands. This indicates the superiority of row culture for smooth bromegrass seed production. Nitrogen fertilizer greatly increased seed yields. Responses to nitrogen were different for the 2 years. Figure 1 shows that spring applications in 1952 were superior to fall applications. The 1952 data indicated that none of the nitrogen treatments were significantly better than 50 pounds per acre applied in the spring. Results in 1953 indicated that fall applications were superior to spring applications. Figure 1 also illustrates the manner in which seed yields on the broad-

Table 1.—Average seed yields from all treatments expressed as pounds of clean seed per acre.

Species	1952	1953	Average
Reed canarygrass	20	144	82
Smooth bromegrass	491	436	464
Orchardgrass	401	608	504
Timothy	142	266	204

Table 2.—Reed Canarygrass seed yields expressed as pounds of clean seed per acre averaged for the 2 years, 1952 and 1953. Means for methods of seeding, nitrogen treatments and rates of seeding based on three replications.

Nitrogen treatments	Seeding rates	Methods of seeding		Ave.—rates at each N treatment	Ave.—N treatments
		Row	Broadcast		
Check	Low	84	2	43	
	High	78	1	39	
	Average	81	2		41
50 lb. N/A. Spring	Low	136	16	76	
	High	107	13	59	
	Average	121	14		68
50 lb. N/A. Fall	Low	120	16	67	
	High	131	17	74	
	Average	125	16		71
50 lb. N/A. Split	Low	136	6	71	
	High	126	8	67	
	Average	131	7		69
100 lb. N/A. Spring	Low	160	88	124	
	High	142	48	95	
	Average	151	68		110
100 lb. N/A. Fall	Low	145	58	101	
	High	149	38	93	
	Average	147	48		97
100 lb. N/A. Split	Low	169	78	124	
	High	168	56	112	
	Average	169	67		118
Average	Low	136	38	87	
	High	128	26	77	
	Methods	132	32		82 Grand Ave.

Differences between:	L.S.D. (0.05)	Values (0.01)
Nitrogen treatments	12.4	16.6
Nitrogen treatments for same method of seeding	17.5	—
Nitrogen treatments for same seeding rate	12.8	—
Nitrogen treatments for same seeding rate, for same method of seeding	18.2	—

Coefficient of variability in percent: 18.96

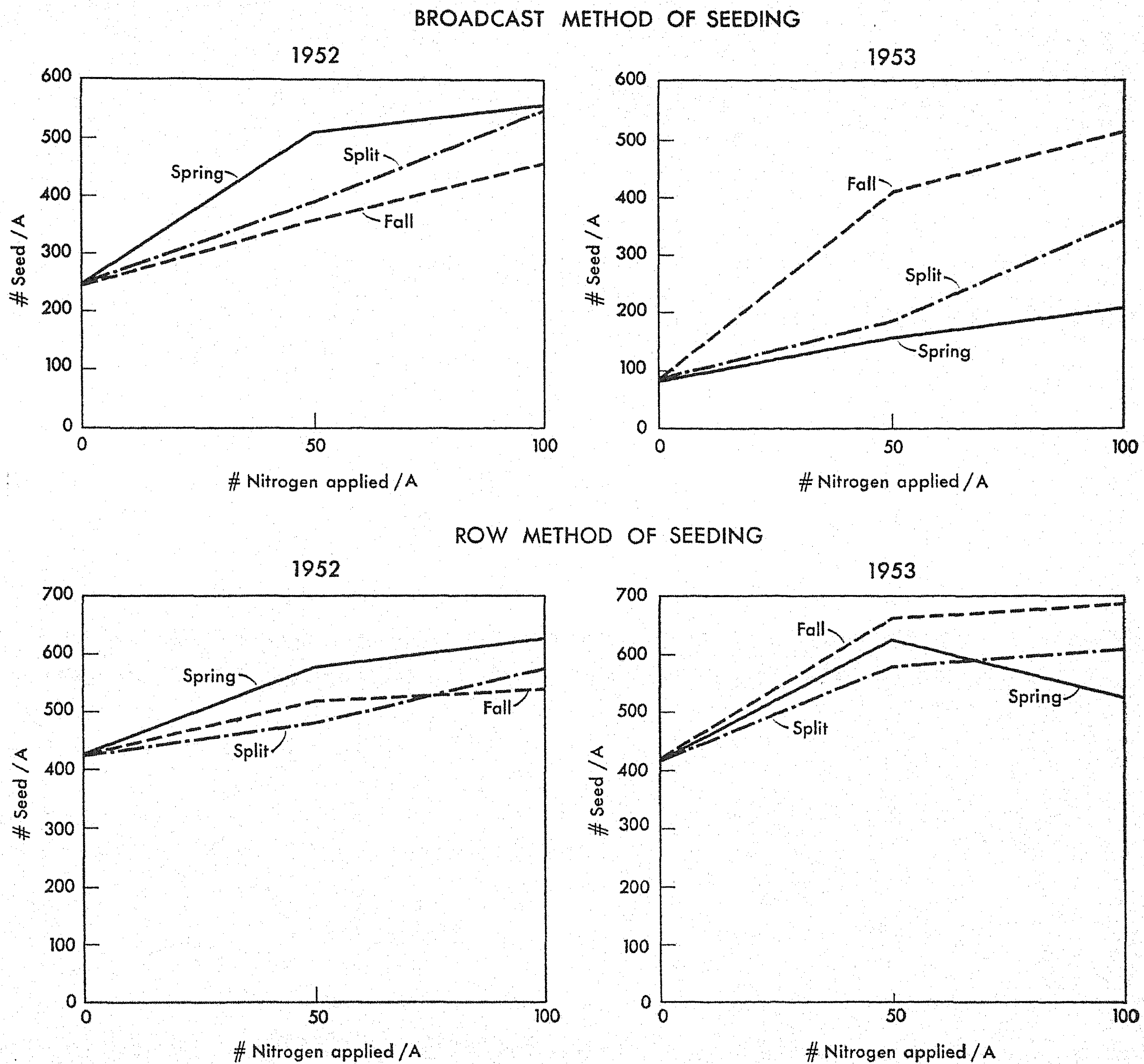

FIG. 1.—Smooth bromegrass seed yield responses to nitrogen fertilization for methods of seeding and years.

cast check plots and those receiving spring nitrogen decreased in the second year. The fall applications stimulated seed production more in the second year than in the first, both in rows and broadcast stands. In 1952 there was no significant difference between seeding rates for either method of seeding. In 1953 the low seeding rate was significantly better than the high rate. The severe reduction in seed production on broadcast stands with two consecutive spring nitrogen applications may be an indication of a sod bound condition. In 1952 the 50 pound per acre spring application on broadcast stand yielded an average of 583 pounds of seed per acre; whereas, in 1953 the same treatment yielded 188 pounds per acre. In 1953, lodging occurred on the plots which received the 100-pound nitrogen treatments and was most severe following spring applications.

Orchardgrass.—The average seed yield of orchardgrass in 1953 showed an increase of 200 pounds per acre over 1952. Based on the two year average, rows were significantly better than broadcast stands; however, there was a significant interaction between methods of seeding and years. In 1952, seed production was best in broadcast plots; whereas, rows were superior in 1953. This superiority was partly due to the significantly greater seed production in rows on the check plots. From 1952 to 1953, average seed production in rows increased from 348 to 710 pounds per acre. Broadcast stands showed a slight increase from 453 to 506 pounds of seed per acre.

An application of 100 pounds of nitrogen per acre in the fall gave a significantly higher seed yield than any other treatment. This superiority was a reflection of the exceptionally high seed yields produced at the low seeding rate

Table 3.—Bromegrass seed yields expressed as pounds of clean seed per acre averaged for the 2 years, 1952 and 1953. Means for methods of seeding, nitrogen treatments, and rates of seeding based on three replications.

Nitrogen treatments	Seeding rates	Methods of seeding: Row	Methods of seeding: Broadcast	Ave.—rates at each N treatment	Ave.—N treatments
Check	Low	388	205	297	
	High	450	143	296	
	Average	419	174		297
50 lb. N/A.	Low	630	399	514	
Spring	High	591	280	435	
	Average	610	340		475
50 lb. N/A.	Low	588	405	496	
Fall	High	603	385	494	
	Average	596	395		495
50 lb. N/A.	Low	525	324	424	
Split	High	542	250	396	
	Average	534	287		410
100 lb. N/A.	Low	542	406	474	
Spring	High	613	373	492	
	Average	577	389		483
100 lb. N/A.	Low	596	561	578	
Fall	High	624	472	548	
	Average	610	516		563
100 lb. N/A.	Low	647	501	573	
Split	High	534	412	473	
	Average	390	456		523
Average	Low	559	400	480	
	High	565	331	448	
	Methods	562	365		464 Grand Ave.

Differences between:	L.S.D. Values (0.05)	(0.01)
Nitrogen treatments	43.0	57.5
Nitrogen treatments for each method of seeding	60.8	81.4
Nitrogen treatments for each seeding rate	78.1	—
Methods of seeding for each seeding rate	59.0	79.0
Nitrogen treatments for each method of seeding for each seeding rate	86.0	115.0

Coefficient of variability in percent: 14.42

of 3 pounds per acre on broadcast plots in both 1952 and 1953. The yields were 617 and 836 pounds of seed per acre, respectively. There was a general tendency for the spring applications of nitrogen to be more effective in stimulating seed yields in rows than in broadcast stands. The lower seeding rate of 3 pounds per acre resulted in significantly higher seed yields than 6 pounds per acre in broadcast plots. In rows, there was no measurable difference due to seeding rates in either year. Lodging occurred with both rates of spring application of nitrogen in 1953 but was much more severe at the higher rate.

Timothy.—Seed yields in the second year were 124 pounds per acre higher than in the first harvest year. Rows yielded significantly higher than broadcast stands in both years. Nitrogen fertilization did not stimulate seed production of timothy to the extent that it did in the other grasses. In 1952 none of the nitrogen treatments was significantly higher than the check. There was a tendency for the fall applications to be superior to spring applications. In 1953,

Table 4.—Orchardgrass seed yields expressed as pounds of clean seed per acre averaged for the 2 years, 1952 and 1953. Means for methods of seeding, nitrogen treatments and rates of seeding based on three replications.

Nitrogen treatments	Seeding rates	Methods of seeding: Row	Methods of seeding: Broadcast	Ave.—rates at each N treatment	Ave.—N treatments
Check	Low	406	214	310	
	High	400	126	263	
	Average	403	170		287
50 lb. N/A.	Low	550	436	493	
Spring	High	584	343	463	
	Average	567	389		478
50 lb. N/A.	Low	541	657	599	
Fall	High	522	548	471	
	Average	532	602		485
50 lb. N/A.	Low	522	474	498	
Split	High	571	372	471	
	Average	546	423		485
100 lb. N/A.	Low	493	501	497	
Spring	High	488	440	464	
	Average	490	470		481
100 lb. N/A.	Low	572	727	650	
Fall	High	556	643	599	
	Average	564	685		625
100 lb. N/A.	Low	575	711	643	
Split	High	626	525	575	
	Average	600	618		609
Average	Low	523	531	527	
	High	535	428	482	
	Methods	529	480		504 Grand Ave.

Differences between:	L.S.D. Values (0.05)	(0.01)
Nitrogen treatments	4.3	5.7
Seeding rates for each method of seeding	17.6	23.8

Coefficient of variability in percent: 11.06

50 pounds of nitrogen per acre gave the highest yields. Nothing was gained by splitting either the 50- or 100-pound rates. These results are reflected in the combined data. Both in rows and broadcast stands 50 pounds of nitrogen per acre applied in the fall was the best treatment. The low seeding rate was significantly better than the high rate although this difference was not great. The high rates of nitrogen caused severe lodging.

SUMMARY AND CONCLUSIONS

Seed yield responses to various cultural practices were studied for reed canarygrass, smooth bromegrass, orchardgrass, and timothy in 1952 and 1953 at the Pennsylvania Agricultural Experiment Station. Variables studied consisted of row and broadcast methods of seeding, 7 nitrogen treatments, and 2 rates of seeding. The experiment was conducted on a soil of medium fertility.

1. Seed production was best in the second harvest year with all grasses except smooth bromegrass.
2. All grasses produced a significantly higher seed yield in rows than in broadcast plots.

Table 5.—Timothy seed yields expressed as pounds of clean seed per acre averaged for two years, 1952 and 1953. Means for methods of seeding, nitrogen treatments, and rates of seeding based on three replications.

Nitrogen treatments	Seeding rates	Methods of seeding: Row	Methods of seeding: Broad-cast	Ave.—rates at each N treatment	Ave.—N treatments
Check	Low	219	153	186	
	High	206	153	180	
	Average	212	153		183
50 lb. N/A. Spring	Low	244	188	216	
	High	258	190	224	
	Average	251	189		220
50 lb. N/A. Fall	Low	258	233	245	
	High	256	224	240	
	Average	257	228		243
50 lb. N/A. Split	Low	224	217	220	
	High	215	193	204	
	Average	220	205		212
100 lb. N/A. Spring	Low	203	185	194	
	High	194	170	182	
	Average	198	177		188
100 lb. N/A. Fall	Low	259	176	217	
	High	240	180	210	
	Average	249	178		214
100 lb. N/A. Split	Low	229	120	174	
	High	219	103	161	
	Average	224	111		168
Average	Low	234	182	208	
	High	227	173	200	
	Methods	230	177		204 Grand Ave.

Differences between:	L.S.D. Values (0.05)	L.S.D. Values (0.01)
Nitrogen treatments	28.2	37.7
Nitrogen treatments for each method of seeding	39.9	53.4
Coefficient of variability in percent: 15:36		

3. For years combined, the low seeding rate produced significantly higher seed yields than the high rate with all grasses.

4. The reed canarygrass data emphasize the value of high applications of nitrogen for maximum seed production. The 100 pound per acre spring application in rows was highest. Since there was no lodging, higher rates might have resulted in still higher yields.

5. Seed yields were much lower in the second year on broadcast plots of smooth bromegrass receiving annual spring nitrogen applications. A 50 pound per acre fall application in rows was superior. Lodging occurred on all plots receiving 100 pounds of nitrogen.

6. With orchardgrass, the 100 pound per acre fall application on broadcast stands was superior to other treatments. Lodging occurred with the spring applications.

7. Nitrogen applications on timothy did not affect seed yield as greatly as on other grasses. A fall application of 50 pounds per acre in rows gave the highest yields.

8. All seed had a satisfactory germination percentage averaging 85 percent or better.

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Effects of Photoperiods on Plant Growth, Flowering, Seed Production, and Tannin Content of *Lespedeza cuneata* Don[1]

R. P. Bates[2]

PROGRESS in an improvement program with sericea lespedeza *(Lespedeza cuneata)* depends in several ways on knowledge of the photoperiodic responses of this species. Slight differences in daylength appear to cause sericea plants to produce cleistogamous instead of chasmogamous flowers. Since both types are used in the breeding of sericea, accurate knowledge of the influence of photoperiods on their production is important. Knowledge of the effects of daylength on growth and seed production would provide a basis for understanding the adaptation requirements of sericea. This study is concerned with effects of different daylengths on plant growth, seed production, proportion of cleistogamous and chasmogamous flowers, time required for flowering, and tannin content of sericea lespedeza.

REVIEW OF LITERATURE

Experimental data concerning responses of sericea lespedeza to photoperiods are meager. Pieters *et al.* (5) reported that during a 1-month period 3 plants of the same original size produced 17 inches of growth under a long day, 9 inches under a normal day, and 6 inches under an 8-hour day. McKee and Hyland (3) pointed out that daylength may be an important factor in determining the type of flower produced. This was indicated by the fact that only apetalous (cleistogamous) flowers were formed, while under extended daylength some petaliferous (chasmogamous) flowers were formed. Stitt *et al.* (7), while conducting a soil type study in relation to tannin content of sericea lespedeza, concluded that variations in light might have some effect on tannin content of this species.

Photoperiod studies with *Lespedeza stipulacea* and *L. striata* have been reported. Smith (6) found a marked photoperiodic response within both species. After 57 days all plants under 7 hours of light had set seed. Plants under 17 hours of light had no seed or flowers after 217 days. No attempt was made to determine the critical photoperiod for these species. Nakata (4) found that 42 days after planting all plants from both species had set mature seed under 10 and 12 hours of light, while plants exposed to 14 and 16 hours of light were growing vegetatively without any sign of flowering after 90 days. Further study indicated that the critical photoperiod for flowering was approximately 13.75 hours and photoperiods over 14 hours resulted in no flowering of *L. stipulacea* and *L. striata*. While studying cleistogamy and development of the embryo sac in *L. stipulacea*, Hanson (2) concluded that daylength probably was one of the factors in determining whether the flower was cleistogamous or chasmogamous.

MATERIALS AND METHODS

This study was made to determine the behavior of *Lespedeza cuneata* plants when subjected to 7 conditions of photoperiod: 8, 10, 12, 13, 14, and 15 hours, and natural day plus 3 hours of light at midnight. The first six light periods were continuous, which resulted in decreased continuous dark periods as length of the light periods increased. Since length of the dark period is the effective factor in determining vegetative and reproductive behavior of plants instead of the length of the light period, the dark period was interrupted at midnight in the seventh treatment to afford a short uninterrupted dark period. During this experiment, which was conducted between April 15 and Sept. 1, natural daylength in the latitude of Beltsville, Md., ranged from 13.5 to 15.1 hours. The experiment was terminated on Sept. 1 at which time plants under the 14-hour, 15-hour and natural day plus 3 hours showed no signs of flowering. Plants under the first 6 photoperiods remained under natural light for 8 hours each day. Additional light was furnished by incandescent bulbs which produced from 20 to 40 foot-candles of light on the plants. Temperature during the study ranged between 80° and 90° F.

Eight sericea strains were exposed to the photoperiods. Plants of 7 strains were obtained from S_1 seed of single plants selected at Beltsville in 1951. Plants of Ga. 13 were from S_1 seed secured from J. M. Elrod of the Georgia Agricultural Experiment Station. A brief description of each strain, as determined under field conditions at Beltsville, Md., is given below. Some of these strains might behave differently at other locations.

Strain	Period of flowering	Maturity	Vegetative growth	Seed production	Tannin content
1-10-14	medium	late	fair	good	low
1-10-20	long	medium	excellent	excellent	medium
1-25-12	long	medium	good	good	medium
5-30-7	long	late	good	excellent	high
5-38-1	short	early	fair	poor	high
82433	medium	medium	good	fair	high
1A-62	short	early	fair	poor	high
Ga. 13	medium	late	fair	excellent	medium

Six plants of each strain were placed in each photoperiod (except the natural day plus 3 hours) at 2, 12, and 20 inches of growth, which gave a total of 1,008 plants in the test. The selfed seeds were planted in 8-inch pots in the greenhouse on April 15, 1952, and resultant seedlings were transplanted to individual 4-inch pots on April 30. Plants remained under natural day conditions until May 5, at which time the 2-inch plants were placed under the various photoperiods. The 12- and 20-inch plants were placed under the various photoperiods on June 3 and June 23, respectively. Plants were placed on hand carts and rolled into and out of six dark chambers. Each chamber was equipped with a time switch to govern each period of artificial light. Six plants of each strain remained on a greenhouse bench for the duration of the experiment and received natural light plus 3 hours of artificial light at midnight.

Data collected included records of plant height, number of days from planting to appearance of first chasmogamous flowers and seed from cleistogamous flowers, total seed production per plant, and tannin content of leaves from plants under selected treatments. Tannin content was determied by the hydrochloric acid-formaldehyde method (1). Tannin determinations were made in duplicate for each composite sample of leaves from six plants. Seed yields and leaf samples were collected 145 days after seeding. Height measurements were made when plants of the 2-, 12-, and 20-inch groups had remained under the photoperiods for 66, 40, and 14 days respectively.

[1] Contribution from the Field Crops Research Branch, A.R.S., U.S.D.A., Beltsville, Md. Part of a thesis submitted to the University of Maryland as partial fulfillment for a Ph.D. degree. Received July 20, 1955.

[2] Formerly Assistant Agronomist, A.R.S., Beltsville, Md.; now Associate Plant Breeder, Samuel Roberts Noble Foundation, Ardmore, Okla. Acknowledgements: The author is indebted to Dr. H. A. Borthwick and Mr. P. R. Henson of the A.R.S., Beltsville, Md., for their fine aid and suggestions during the experiment and while preparing the manuscript.

Table 1.—Average height of *L. cuneata* strains subjected to different photoperiods at different stages of growth.

Photoperiod	Plant heights following treatments started at different stages of growth		
	2-inch	12-inch	20-inch
hours	inches	inches	inches
8	2.7	13.5	20.6
10	2.8	12.3	21.4
12	4.9	14.2	22.1
13	11.3	16.4	22.3
14	14.8	16.8	22.4
15	14.1	16.8	22.8
Mean	8.4	15.0	21.9

RESULTS AND DISCUSSION

There was very little growth in plants subjected to 8, 10, or 12 hours of light daily at any of the 3 stages of growth but plants in the 3 longest photoperiods increased height appreciably, particularly in the 2-inch groups (table 1).

Most of the eight strains showed growth differences similar to the averages in table 1. The bushy or semi-prostrate strains were as tall, if not taller, in the 13-hour as in the 14-hour photoperiod. Typical response of plants placed under the various daylengths when 2 inches high is shown by strain 1–10–20 in figure 1.

Interactions were found between strains and photoperiods, the greatest being between the 13- and 14-hour photoperiods (figures 2 and 3). Plants of strain 5–38–1 were the smallest of those under 13 hours of light, but largest of those under 14 hours of light. Growth of some strains was retarded more by short days than was growth of others. Very little growth was made by any strain when grown under 8 or 10 hours of light. Some strains made fair growth under 12 and 13 hours, but none made maximum growth under these daylengths.

Strains such as 5–38–1 grew very slowly under a 13-hour light period, but grew rapidly under 14 hours of light. Other strains such as 5–30–7 made more erect growth under 13 hours than under 14 hours of light. These strains appeared to branch more under the 14-hour photoperiod than under the 13-hour light period. Variation in response among the strains suggests the possibility of developing varieties that are better adapted to a given location. The fact that some strains made good growth under several photoperiods indicates that some strains might have a wider range of adaptation than others.

Strain 1–10–20 was the most consistent producer of chasmogamous flowers, followed by 5–30–7 and Ga. 13. Strains 5–38–1 and 1A–62 produced chasmogamous flowers only under 13 hours of light and when placed under the photoperiod at 2 inches of height. Table 2 shows that the majority of chasmogamous flowers were produced under 13 hours of daily light. Photoperiods of 14 hours, 15 hours, and natural day plus 3 hours of light at night had not produced chasmogamous flowers after 145 days following seeding.

Seed from cleistogamous flowers were formed about the same time or slightly after chasmogamous flowers were formed. In several cases, however, seed from cleistogamous flowers were produced where no chasmogamous flowers were formed. Table 3 shows that when plants were placed

Fig. 1.—Plants from strain 1–10–20 of *L. cuneata* after remaining under 7 different photoperiods for 90 days. Plants were placed in photoperiods at 2 inches of height.

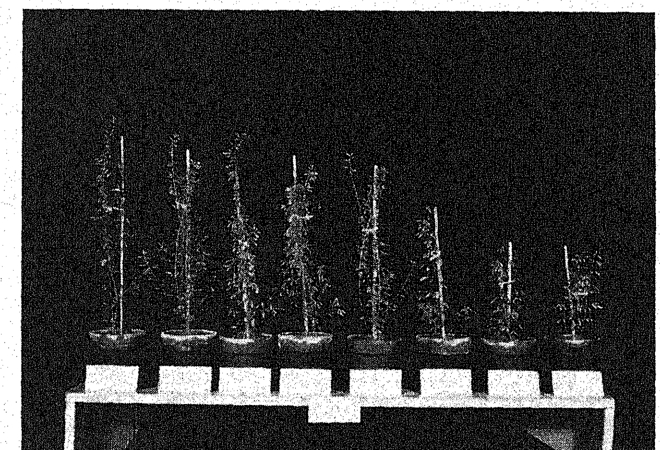

Fig. 2.—Plants from 8 strains of *L. cuneata* after remaining under a 13-hour photoperiod for 90 days. Plants were placed in the photoperiod at 2 inches of height.

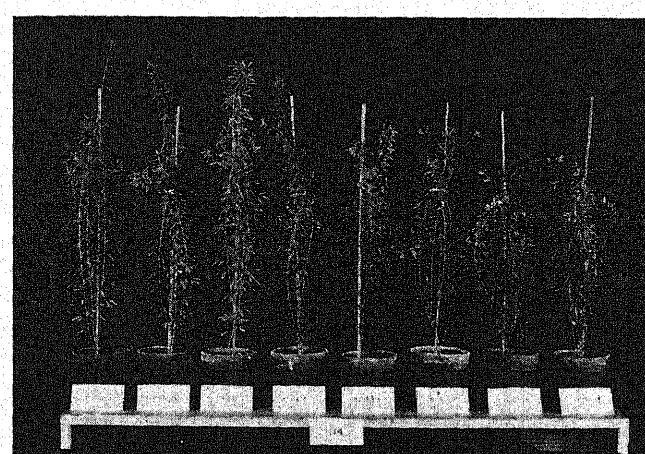

Fig. 3.—Plants from eight strains of *L. cuneata* after remaining under a 14-hour photoperiod for 90 days. Plants were placed in the photoperiod at 2 inches of height.

Table 2.—Days after seeding before chasmogamous flowers appeared on strains of *L. cuneata* under four different photoperiods.

Photoperiods hours	Days before chasmogamous flowers were noted							
	1–10–14	1–10–20	1–25–12	5–30–7	5–38–1	1A–62	82433	Ga. 13
				Plants 2 inches high				
8, 10, 12	*	*	*	*	*	*	*	*
13	118	73	73	73	118	118	118	118
				Plants 12 inches high				
8, 10	*	*	*	*	*	*	*	*
12	*	79	*	79	*	*	*	96
13	*	79	83	79	*	*	*	93
				Plants 20 inches high				
8	93	93	*	*	*	*	95	93
10	93	93	*	93	*	*	*	*
12	95	95	105	93	*	*	*	107
13	118	104	104	101	*	*	118	118

* No chasmogamous flowers formed.

Table 3.—Days after seeding before seed form cleistogamous flowers appeared on strains of *L. cuneata* under four different photoperiods.

Photoperiods hours	Days before seed from cleistogamous flowers were noted							
	1–10–14	1–10–20	1–25–12	5–30–7	5–38–1	1A–62	82433	Ga. 13
				Plants 2 inches high				
8, 10, 12	*	*	*	*	*	*	*	*
13	86	73	73	73	73	77	93	93
				Plants 12 inches high				
8	83	79	79	79	79	83	83	93
10	83	79	79	79	79	*	90	86
12	79	77	79	77	83	83	86	79
13	118	93	93	93	86	90	90	101
				Plants 20 inches high				
8	96	96	101	93	101	101	96	96
10	96	96	109	96	101	101	109	101
12	104	96	104	96	101	104	101	101
13	118	118	118	118	118	118	118	118

* No seed from cleistogamous flowers appeared.

under light periods of 8, 10, 12, and 13 hours at 12 or 20 inches of height, cleistogamous flowers were formed. When plants were placed under the photoperiods at 2 inches of height, only those under 13 hours of light formed cleistogamous flowers. There was no great difference among strains in formation of cleistogamous flowers as there was in the formation of chasmogamous flowers.

Sericea lespedeza strains may behave differently, but both chasmogamous and cleistogamous flowers were formed under 13 hours of daylight. Total seed production was also greatest under the 13-hour photoperiod. There was a difference in seed setting among different strains. These studies were under greenhouse conditions, and whether the same relative amounts of seed would be produced under field conditions is not known. In all strains seed production response to photoperiods was great. Some strains produced more seed than others. Ga. 13 had the largest mean yield, while 1–25–12 and 1A–62 had the smallest. During the course of the experiment no seeds were produced on plants under the 14-hour, 15-hour, and natural day plus 3 hours photoperiods. Table 4 shows that under 13 hours of light all strains produced some seed. Yield differences were not significant among the 8-, 10-, and 12-hour photoperiods. Very few, if any, seeds were produced from chasmogamous flowers. The reason for failure of seed set from these flowers is not known; however, seed production from chasmogamous flowers frequently is low under greenhouse conditions.

Tannin content of leaves appeared to be affected greatly by different daylengths. Table 5 shows that tannin content of the leaves increased as daylengths increased. Tannin percentages obtained under natural day plus 3 hours were about the same as those obtained from these strains under field conditions during the middle of August at Beltsville, Md. An increase in daylength affected some strains more than it did others. This interaction indicates that low-tannin strains might have to be developed in the area in which they are to be grown, and also that low-tannin strains may be developed more successfully in some areas than in others. Of course, several other environmental factors may

Table 4.—Seed production from 8 strains of *L. cuneata* under 4 different photoperiods.

Photoperiods hours	Mean grams of seed produced per plant								
	1-10-14	1-10-20	1-25-12	5-30-7	5-38-1	1A-62	82433	Ga. 13	Mean
	Plants 2 inches high								
8	*	*	*	*	*	*	*	*	*
10	*	*	*	*	*	*	*	*	*
12	*	*	*	*	*	*	*	*	*
13	0.01	0.11	0.04	0.68	0.72	0.18	0.49	0.33	0.32
	Plants 12 inches high								
8	0.02	0.03	0.01	0.02	0.01	0.01	*	0.01	0.01
10	.01	.05	.01	.03	.01	*	0.01	.01	.02
12	.08	.06	.03	.06	.01	.01	.01	.18	.06
13	.55	.54	.25	.65	.03	.14	.22	1.40	.47
	Plants 20 inches high								
8	0.21	0.18	0.03	0.13	0.02	0.03	0.15	0.52	.016
10	.18	.15	.03	.25	.02	.02	.11	.17	.12
12	.19	.35	.03	.36	.09	.01	.13	.29	.18
13	.64	.78	.54	.57	.23	.47	.74	1.00	.62
Mean	.21	.25	.11	.31	.13	.10	.20	.44	.22

L.S.D. for:	0.05	0.01
Strains	.17	.23
Photoperiods × heights	.18	.24

* No seed were produced.

Table 5.—Percent of tannin in leaves of *L. cuneata* strains grown under three different photoperiods.

Strains	8-hour	13-hour	Natural day plus 3 hours at night	Mean
1-10-14	3.0	6.5	8.3	5.9
1-10-20	7.3	10.6	12.1	10.0
1-25-12	6.7	8.7	11.3	8.9
5-30-7	9.9	7.3	12.9	10.0
5-38-1	7.6	6.2	13.2	9.0
1A-62	5.2	7.9	11.2	8.1
82433	6.9	10.3	9.3	8.8
Ga. 13	6.8	9.3	13.5	9.9
Mean	6.7	8.4	11.5	8.9

L. S. D. for:	0.05	0.01
Strains	2.7	3.8
Photoperiods	1.5	2.1

affect the tannin content of a given strain at a given location.

SUMMARY

Very little vegetative growth was obtained from *L. cuneata* plants grown under daylengths of less than 13 hours. The 13-hour day produced fair growth and resulted in the most flowering and best seed production. The 13-hour photoperiod was the only treatment which resulted in production of chasmogamous flowers by all strains. Neither cleistogamous nor chasmogamous flowers were produced under photoperiods of 14 hours or longer. Tannin content of sericea lespedeza leaves increased as daylength increased. Different strains of sericea behaved differently under different daylengths.

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The Response of Crested Wheatgrass and Volunteer Sweetclover to Nitrogen and Phosphorus Under Dryland Conditions[1]

R. E. Stitt, J. C. Hide, and Elmer Frahm[2]

CRESTED wheatgrass is one of the most important cultivated grasses for areas of limited precipitation in the Northern Great Plains and Rocky Mountain regions of the United States. It consists of numerous types of *Agropyron cristatum* (L.) Gaertn. and *A. desertorum* (Fisch.) Schult. Crested wheatgrass is an introduction from Asia and is now an important hay and pasture crop in the western United States. Production has usually been considered to vary with rainfall, but observations over a period of years have shown that yields become progressively lower with an increase in age of stand. This phenomenon is thought to be associated with low availability of nitrogen in the cool spring season of growth.

EXPERIMENTAL PROCEDURE

Since general observations indicated that commercial fertilizers would probably increase grass growth, a fertilizer study involving nitrogen and phosphorus was undertaken. The field selected was seeded to a mixture of Standard and Fairway crested wheatgrass in 1932 and is located on the Central Montana Branch Station at Moccasin. The grass stand was relatively pure, excepting that in some years volunteer sweetclover (*Melilotus officinalis* (L.) Lam.) was also present. The Judith clay loam soil of this field, because of underlying gravel at depths varying between 15 and 40 inches, has only a moderate moisture storage capacity.

In April 1946, ammonium nitrate was applied with a fertilizer drill at rates which provided 0, 25, 50, 100, 150, and 200 pounds of nitrogen per acre. Superphosphate (42% P_2O_5) was applied across the ammonium nitrate plots at the rates equivalent to 0, 20, 40, and 80 pounds of P_2O_5 per acre. The treatments were replicated three times, and both the nitrogen and phosphate treatments were randomized within the blocks. In 1946, two separate 3- by 18-foot areas were harvested from each plot, one for hay on June 25 and the second for hay and seed on Aug. 9. In 1947, the residual effects of the fertilizers were measured by harvesting 3- by 16-foot areas for hay on July 16 and square meter areas of the nitrogen treatments without phosphate on Aug. 15 for hay and seed yields and chemical analyses. Square meter samples were harvested for chemical anlaysis on July 8, 1948, from the high nitrogen plots only, since the prevalence of volunteer sweetclover in the other plots would have complicated the interpretation of data.

In April of 1947, a second experiment was started on an adjacent area. Ammonium nitrate at nitrogen rates of 0, 25, 50, 100, and 200 pounds per acre, and superphosphate (42% P_2O_5) at rates of 0, 20, 40, 60, and 80 pounds of P_2O_5 per acre were applied in the 25 possible combinations arranged in a triple lattice design with 3 replications. Areas of these plots were harvested for hay on Aug. 15, 1947. A hay harvest to obtain residual effects was also made on July 8, 1948.

RESULTS

Yield data were secured from all plots for the first 2 years following fertilizer application and from selected plots of the area fertilized in 1946 in their third year of growth. The growth harvested in 1946 was entirely crested wheatgrass, since second-year sweetclover plants were not present. Under the conditions of this experiment, first-year sweetclover did not grow high enough to be cut by the mower. In 1947, there was an abundance of second-year sweetclover growing in the area selected for the fertilizer applications, but on the area which had been fertilized in 1946, the stand of second-year sweetclover was related to the fertilizer treatment.

Response to Nitrogen Fertilizer

First-year effects.—The hay yields, as affected by ammonium nitrate and superphosphate in the year of application, are given in tables 1 and 2. Marked responses were obtained from almost all levels of nitrogen application, without regard to phosphate level. In the June harvest in 1946, all of the plots receiving ammonium nitrate gave a significant increase in yield over the untreated plots. In general, the yields from this early harvest increased progressively with the rates of application of nitrogen fertilizer though the yield increase per unit of applied nitrogen decreased. The 25-pound nitrogen application consistently brought about a greater increase in yield than any additional similar increment in this harvest.

In the harvest representing total growth up to Aug. 9, 1946, the 25-pound nitrogen application had almost no influence on yield. Evidently this light rate of application did not provide adequate nitrogen to stimulate growth late in the season. The yields from the other ammonium nitrate

Table 1.—Yields of crested wheatgrass in pounds per acre harvested at two harvest dates in 1946 from adjoining plots following April 1946 application of nitrogen and phosphate.

Pounds P_2O_5 per acre	Pounds nitrogen per acre						Average
	0	25	50	100	150	200	
First cutting harvested June 25, 1946							
0	441	598	591	735	729	877	662
20	351	527	699	775	743	873	661
40	345	527	619	641	777	795	617
80	306	552	686	792	729	1055	681
Average	361	551	649	736	744	900	
First cutting harvested August 9, 1946							
0	839	734	1350	1523	1464	1699	1267
20	705	698	1172	1305	1393	1785	1176
40	645	696	1128	1290	1209	1651	1103
80	746	829	1242	1491	1389	1812	1251
Average	733	739	1223	1402	1364	1737	

L.S.D. 5% level	Means N	Means P_2O_5	Among treatments
June 25 harvest	129	N-S	154
August 9 harvest	228	N-S	264

[1] Contribution from the Field Crops Research Branch, A.R.A., U.S.D.A., and the Montana Agr. Exp. Sta. Published with the approval of the Director of the Montana Agr. Exp. Sta. as Journal Series Paper No. 219. Presented in part at the meetings of the American Society of Agronomy in Cincinnati, Ohio, Nov. 20, 1947. Received Aug. 1, 1955.

[2] Associate Agronomist, Research Professor of Soils, and Professor of Chemistry, respectively. Acknowledgement is due Ralph M. Williams, formerly Superintendent, and James L. Krall, Superintendent of the Central Montana Branch Station, for assistance in carrying out these investigations.

treatments were nearly double those secured from the June harvest. On the August date of harvest, the 50-pound rate was most efficient.

Table 2 presents yields taken on July 17, 1947, from plots fertilized that spring. Nitrogen responses were obtained on crested wheatgrass at all levels of nitrogen application. When all phosphate treatments are averaged, each nitrogen increment progressively increased yields, and the maximum yields were greater than in the previous year. These plots all contained second-year sweetclover on which nitrogen responses were evident. The 25-pound nitrogen application provided the maximum stimulation on second-year sweetclover growth, probably because at the heavier rates of nitrogen fertilization, the grass provided excessive competition for the sweetclover. Nitrogen responses to sweetclover were obtained only in this harvest, where the fertilizer was applied to plants which were already established.

Second-year effects.—The yields obtained for the second-year of growth after the ammonium nitrate application are given in tables 3 and 4.

The grass in the plots treated with ammonium nitrate shows yield increases from residual nitrogen during the year following application. In 1947, yield increases from nitrogen applied in 1946 were significant at the 50-pound and higher rates, as shown in table 3. From table 4 it is observed that in 1948 a significant increase from 1947

Table 2.—Yields of crested wheatgrass, sweetclover, and total hay in pounds per acre harvested July 17, 1947, after April 1947 application of nitrogen and phosphate.

Pounds P_2O_5 per acre	Pounds nitrogen per acre					Average
	0	25	50	100	200	
			Crested wheatgrass			
0	387	602	1236	1690	1465	1076
20	246	607	1175	1844	1890	1152
40	320	656	1080	1750	2406	1243
60	241	758	926	1477	2204	1121
80	316	543	1377	1922	2405	1313
Average	302	633	1159	1737	2074	
			Sweetclover			
0	366	862	602	621	712	633
20	791	703	732	574	1083	777
40	533	851	617	697	719	683
60	539	792	894	688	678	718
80	466	975	793	640	705	716
Average	539	837	727	644	779	
			Total hay			
0	753	1464	1838	2311	2177	1709
20	1037	1310	1907	2418	2973	1929
40	853	1507	1697	2447	3125	1926
60	780	1550	1820	2665	2882	1839
80	782	1518	2170	2562	3110	2029
Average	841	1470	1886	2381	2853	

L.S.D. 5% level	Means N	Means P_2O_5	Among treatments
Crested wheatgrass	63	63	141
Sweetclover	142	N.S.	319
Total hay	188	188	420

applied nitrogen was not encountered until the 100-pound rate of application was reached. Each increment of nitrogen fertilizer progressively reduced the yield of second-year sweetclover in the mixture. Apparently this yield reduction was caused through loss of stand during the seedling year from excessive competition by the nitrogen-stimulated grass.

Third-year effects.—In 1948, the plots which received 200 pounds of nitrogen in 1946 were free from second-year sweetclover, but sweetclover growth was abundant on all other plots. Thus, the stimulation to grass growth in 1947 from nitrogen applied in 1946 at rates of 150 pounds per acre or less was not great enough to exclude the establishment of sweetclover seedlings.

Response to Phosphate Fertilizer

First-year effects.—Yields of crested wheatgrass for 1946, as affected by the superphosphate during the application year, are given in table 1. Sweetclover did not contribute to yields in this crop. The average crested wheatgrass yields did not show significant differences among phosphate treatments.

In 1947, the grass yields were increased by the use of superphosphate, as given in table 2. The increase in rate of application of P_2O_5 gave progressive yield increases, except for the 60-pound rate, which yielded less than the 20-pound rate. The yield of second-year sweetclover was not significantly affected by phosphate treatment in 1947 when the phosphate was applied to established plants.

Table 3.—Yields of crested wheatgrass, sweetclover, and total hay in pounds per acre harvested July 16, 1947, after April 1946 application of nitrogen and phosphate.

Pounds P_2O_5 per acre	Pounds nitrogen per acre						Average
	0	25	50	100	150	200	
			Crested wheatgrass				
0	598	708	799	698	1054	1420	880
20	470	630	777	741	994	1508	853
40	519	711	690	802	998	1468	865
80	445	616	865	702	885	1428	824
Average	508	666	783	736	982	1456	
			Sweetclover				
0	189	267	134	15	13	0	103
20	582	383	111	16	6	49	191
40	403	327	88	41	39	10	151
80	595	541	137	75	18	0	228
Average	442	380	118	37	19	15	
			Total hay				
0	787	975	933	713	1067	1420	983
20	1052	1013	888	757	1000	1557	1044
40	922	1038	778	843	1037	1478	1016
80	1040	1157	1002	777	903	1428	1052
Average	950	1046	901	773	1001	1471	

L.S.D. 5% level	Means N	Means P_2O_5	Among treatments
Crested wheatgrass	162	N.S.	421
Sweetclover	103	N.S.	260
Total Hay	176	N.S.	381

Second-year effects.—The influence of phosphate on the yield of the second-year crop of crested wheatgrass and sweetclover following the application of superphosphate is given in tables 3 and 4. The average yield for each phosphate level for both sweetclover and crested wheatgrass does not show a significant response to the residual effect of phosphate, although the rates above 40 pounds of P_2O_5 per acre gave actual yield increases. The yield increase in total hay was significant at the 5% level in the 1948 harvest for a phosphate application rate of 80 pounds per acre. There was a trend for yields to increase with increasing rates of application.

Without nitrogen, superphosphate tended to encourage the establishment of sweetclover, and this shows up in its effect on yields the year after application, as shown in tables 3 and 4. The increased growth of sweetclover exceeds any reduction in grass yield that may have occurred. Thus, the use of a phosphate fertilizer shows promise as a method of increasing hay yields from these areas by encouraging sweetclover growth.

Combined Effect of Nitrogen and Phosphate Fertilizers on Hay Yields

Hay yields by individual treatments are presented in tables 1 to 4. Without nitrogen, phosphorus fertilizers had slight influence on crested wheatgrass yields, whereas at high rates of nitrogen application, phosphorus increased grass growth at some harvest dates. The influence of phosphate on grass yields was erratic when intermediate rates of nitrogen were applied. The phosphate response at high nitrogen levels in both the year of application and the year following application were considerably greater in the plots on which the fertilizer was applied in 1947 than on the plots fertilized in 1946.

Table 4.—Yields of crested wheatgrass, sweetclover, and total hay in pounds per acre harvested July 8, 1948, after April 1947 application of nitrogen and phosphate.

Pounds P_2O_5 per acre	Pounds nitrogen per acre 0	25	50	100	200	Average
	Crested wheatgrass					
0	877	1076	944	1433	1686	1203
20	972	736	941	1187	2168	1201
40	814	909	1002	1294	1899	1184
60	839	1017	987	1336	2000	1236
80	760	932	1026	1417	2155	1258
Average	952	934	980	1334	1981	
	Sweetclover					
0	436	18	4	0	0	92
20	157	5	0	7	0	34
40	1302	81	4	0	0	277
60	1314	170	3	0	0	297
80	1223	68	3	0	0	259
Average	886	68	3	1	0	
	Total hay					
0	1313	1094	948	1433	1686	1295
20	1129	741	941	1194	2168	1235
40	2116	990	1006	1294	1899	1461
60	2153	1187	990	1336	2000	1533
80	1983	1000	1029	1417	2155	1517
Average	1738	1002	983	1335	1981	

L.S.D. 5% level	Means N	Means P_2O_5	Among treatments
Crested wheatgrass	176	N.S.	340
Sweetclover	242	N.S.	769
Total hay	245	245	548

Table 5.—Protein and phosphorus content of crested wheatgrass harvested June 25, 1946 as affected by fertilizer treatment.

Treatment Lbs./Acre P_2O_5	Nitrogen	Composition of hay (12% moisture) Protein Percent	Protein Lbs./Acre	Phosphorus Percent	Phosphorus Lbs./Acre
0	0	10.8	48	0.19	0.80
	25	11.3	67	0.18	1.08
	50	13.3	79	0.18	1.09
	100	13.9	102	0.17	1.23
	150	14.8	108	0.19	1.39
	200	16.7	147	0.16	1.43
80	0	10.8	33	0.19	0.60
	25	11.8	65	0.19	1.03
	50	13.4	91	0.19	1.33
	100	13.8	109	0.20	1.57
	150	15.6	114	0.20	1.46
	200	17.5	184	0.20	2.07
L.S.D. 5% level		1.2	22	—	0.34

On the area fertilized in 1947, a volunteer stand of sweetclover had been established the previous year, so that the fertilizer was applied early in the second year of its growth. Under these circumstances (table 2), the combined use of nitrogen and phosphate tended to increase yields, although there was considerable variation among some treatments, which did not follow a consistent pattern.

The use of phosphate without nitrogen increased seedling sweetclover survival at the 20-pound and higher rates in 1946 and at 40-pound and higher rates in 1947. This did not affect sweetclover yields until it produced hay in its second year of growth, as shown in tables 3 and 4. When nitrogen was applied with the phosphate, only a few seedling sweetclover plants became established, and phosporus could have no effect on sweetclover yields.

Protein and Phosphorus

Determinations of protein and phosphorus were made on samples from the untreated and high phosphate plots at the different nitrogen levels from the harvest of June 25, 1946. These samples consisted of pure crested wheatgrass, since sweetclover did not contribute to hay yields in this crop. The data are presented in table 5. Percentage and yield of protein and yield of phosphorus increased with the ammonium nitrate rates. Superphosphate significantly changed the percentage of phosphorus at only 2 of the 3 higher rates of phosphate application and did not influence protein content. Superphosphate increased the yield of protein at the high rate of nitrogen application.

Samples were harvested in 1948 from the plots receiving high nitrogen and varying rates of phosphate in 1946. Volunteer sweetclover was not present in these plots. These data are not presented in the table, but the samples contained an average of 7.09% protein and 0.16% phosphorus. Neither protein nor phosphorus content of crested

Table 6.—Seed yields per acre and germination of crested wheatgrass as affected by ammonium nitrate and treble superphosphate.

Pounds N/Acre	Fertilizer applied 1946				Applied 1947	
	Harvested 1946			Harvested 1947	Harvested 1947	
	No P_2O_5	80 lbs./A P_2O_5	Germination of seed	No Phosphate	No P_2O_5	80 lbs./A P_2O_5
	Lbs.	Lbs.	%	Lbs.	Lbs.	Lbs.
0	15	15	87	15	4	4
25	11	14	87	8	22	18
50	15	9	84	15	33	41
100	21	19	84	8	49	38
150	12	8	81	28	—	—
200	13	15	80	29	40	63
L.S.D. 5% level	4	4	5	—	14	14

wheatgrass was affected significantly by the applications of superphosphate, although the combined phosphate and nitrogen treatment gave a higher yield of phosphorus than did nitrogen alone.

Seed Yields of Crested Wheatgrass

Crested wheatgrass seed yields were obtained on Aug. 9, 1946, and on Aug. 15, 1947, and the data are given in table 6. Yields of seed in 1946 were very low, although the 100-pound nitrogen rate gave significant increase over the check. The seed yields for the rates above 100 pounds nitrogen were lower or equal to those of untreated plots. Germination of the 1946 seed was reduced slightly by the 150- to 200-pound nitrogen rates.

Seed yields in 1947 were not affected by fertilizer applied in 1946.

Nitrogen applied in 1947 increased crested wheatgrass seed yields during that year. The nitrogen rates of 200 pounds did not yield any more than the 100-pound rate. With 100 pounds or less of nitrogen, phosphate did not increase seed production. However, the largest amount of seed was obtained from the use of 80 pounds phosphate with 200 pounds nitrogen.

DISCUSSION

This fertilizer study was conducted at the Central Montana Branch Station, where the 1909 to 1953 average annual precipitation is 15.00 inches, and the April 1 to Sept. 30 rainfall averages 11.16 inches. The elevation is 4,250 feet. Climatic conditions in the area are considered favorable for the growth of crested wheatgrass. Crested wheatgrass yields, where no fertilizer was used, were much lower in the 1946 to 1948 period than they had been during the preceding 4-year period. During the period of this study, both the growing season precipitation and the annual precipitation were 1 to 3 inches above average. However, the Oct. 1 to May 31 precipitation for 1946, 1947, and 1948 were, respectively, 5.61, 7.51, and 6.59 inches, with the long-time average for this period being 7.12 inches. Since in the Northern Plains area, winter moisture is more efficiently stored than summer moisture, and since crested wheatgrass makes a high proportion of its growth early in the season, it appears that from the moisture standpoint, the study was conducted under approximately average conditions.

It is widely believed that, under Great Plains conditions, available moisture determines the crop production potential of the area and that low soil fertility seldom limits crop production. However, for grass production, nitrogen applications have more than doubled yields in the year of application, and from heavy nitrogen applications, residual effects have carried into the third crop season. Under the rainfall conditions prevailing in the area, nitrogen would rarely be leached from the soil. Where heavy vegetative responses to nitrogen were obtained, the increases in seed yields were slight.

Although the response of crested wheatgrass to nitrogen was favorable, it is doubtful that applications under dryland conditions would be generally economical with present fertilizer costs. While the use of nitrogen more than doubled the yield of crested wheatgrass in 1946, when relatively pure stands occurred, the yield of protein per acre was increased between 3 and 5 times. In order to properly evaluate the economic feasibility of the practice, feeding or grazing trials would be necessary. The retaining of available nitrogen in the soil for long periods of time might make high rates of application practical. Lower cost of nitrogenous fertilizers would also alter the economy of their use for dryland grass and make possible a much higher grass production level.

Sweetclover was maintained in the crested wheatgrass stands only when phosphate was applied without nitrogen. When phosphate fertilizer increased the yield of sweetclover, the yield of crested wheatgrass was either unaffected or only slightly influenced. Thus, the yield of total hay was increased approximately in direct proportion to the increase in sweetclover growth. Sweetclover provided from one-fourth to over one-half of the total forage yield when present. Hence, the use of sweetclover or other adapted legumes in combination with crested wheatgrass should be more economical than the use of nitrogenous fertilizer. The use of phosphatic fertilizer on phosphate deficient soils under some dryland conditions should be of value in increasing the sweetclover in the mixture. The study has clearly demonstrated that, under the dryland conditions prevailing in the area, the water available to the crop is not the only variable which influences the yielding ability of a grass crop or a grass-legume mixture. Further studies are needed to determine if fertilizers can be used to increase

the efficiency of water use in the area. If the fertility level can be balanced with the potential water supply for the crop, it is probable that the efficiency of both water and fertilizer use can be increased. This will require a much more detailed type of experiment than has yet been undertaken.

SUMMARY

Two studies were made on the effects of different rates of application of ammonium nitrate and superphosphate alone and in combination to a mixed stand of crested wheatgrass and sweetclover that had been established 14 years.

In 1947, 25 pounds of nitrogen per acre increased the growth of crested wheatgrass during the application year, but similar applications in 1946 did not produce significant season-long yield increases, although it increased the early growth. The higher rates of application increased the yields in both 1946 and 1947.

Rates of application of 100 to 200 pounds per acre of nitrogen increased yields of crested wheatgrass in the second year following application.

Ammonium nitrate applications decreased the stand of second-year sweetclover the year following the application, apparently by discouraging the establishment of seedlings during the year of nitrogen application. The higher rates kept out sweetclover even in the third year following application.

Superphosphate increased the stands of sweetclover by helping survival during the seedling stage. The growth of grass was also increased when the superphosphate was used with a high rate of ammonium nitrate.

Growing sweetclover or other adapted legumes with the grass would probably be a more economical method of obtaining higher yields under dryland conditions than the application of commercial nitrogenous fertilizers. The use of superphosphate to encourage the establishment of sweetclover stands may be profitable.

An Evaluation of S_1 and Polycross Progeny Testing in Alfalfa[1]

R. L. Davis[2]

THE interest in ascertaining the predictive value of various methods of progeny testing is evidenced by the recent papers on the subject. Characteristics evaluated have varied depending on the species. Various progeny relationships have been investigated in the following species: bromegrass (3, 8, 9, and 10); orchardgrass (6, 11, 12, and 15); alfalfa (13, 16, and 17); sweet clover (5); timothy[3] (11); and crested wheatgrass (8).

When the data are summarized, the inconsistencies among and within the various species make it difficult for the plant breeder to choose an efficient progeny test. Part of this inconsistency is undoubtedly due to differences in cultural practices such as row seedings compared with spaced plantings, the polyploidy of the species, types of pollination, composition of open-pollinated and polycross nurseries, genetic variability among the lines tested, and number of years tested.

The purpose of this paper is to present data and discuss S_1 and PX (polycross) progeny testing. Various characters were evaluated. Synthetic yields were compared to clonal and PX progeny yields.

REVIEW OF LITERATURE

Weiss, *et al.* (15) in studies with orchardgrass using spaced clonal plants and row seeded OP (open-pollinated) progenies found both negative and positive correlations for yield. The OP progeny was from seed collected from only one clonal plant. When SC (single cross) progeny yields were compared to the clones, the *r* values were significantly negative to significantly positive. This was true also for SC yields vs. OP yields. Orchardgrass data of Kalton, *et al.* (6) showed a negative to significant positive correlation for yield for S_0 with S_1 and S_0 with S_2 plants. Heritability was negative to low, suggesting environment was the major influence. In contrast, Oldemeyer and Hanson (12) obtained significant correlations for yield between clones and SC; clones and PX; and SC and PX ranging from 0.63 to 0.74 for 10 df. The interaction for broadcast vs. spaced plantings was also significant.

In bromegrass testing, Knowles (9) observed significant correlations for yields between top crosses and OP progenies produced in a non-replicated clonal nursery. He suggested no material benefits from replicated clonal nurseries for production of OP seed. This is at variance with recent data (4). Heritability calculated from progeny-parent regression varied from 24 to 68% and from 68 to 100% for yield and creeping habit, respectively. However, in 1950 Knowles (8) obtained non-significant correlations between the yields of controlled crosses and OP progenies. This was attributed to selfing within the controlled crosses.

McDonald, *et al.* (10) computed the yield relationships between S_0, S_1 and OP bromegrass plants in both spaced and row seedings. One significant correlation of 0.54 for 38 df was obtained for S_0 spaced plants and OP spaced progenies. Other associations were low and both positive and negative, suggesting an interaction with method of seeding. Hawk and Wilsie with bromegrass (3) found all yield correlations between parental clones and OP progenies, and among the various harvests of OP progenies highly significant. The r values for the relationship between S_0, S_1, S_2, and the OP progenies of these 3 generations ranged from 0.06 to 0.55 for 24 df. However, the S_1 and S_2 generations were represented by a selected and very limited sample.

In evaluating alfalfa, Tysdal and Crandall (13) recorded similar rankings for 6 clones using top cross, PX, and SC progeny evaluations. Wilsie (16) in a space-planted clonal, S_1, and OP nursery obtained significant yield correlations between clones and OP, between clones and S_1, and between S_1 and OP. Wilsie and Skory (17) reported significant r values between OP and S_1 progenies.

Significant correlations were obtained from sweet clover yields between OP and PX; S_1 and OP; and S_1 and PX of 0.70, 0.65 and 0.80 respectively with 17 df (5).

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[2] Associate Professor in Agronomy.

[3] Wilder, W. G. Methods of evaluating clones of timothy, *Phleum pratense*, and their breeding behavior. M.S. thesis. Purdue Univ. 1951.

Low and non-significant correlations were reported by Wilder[4] with timothy between clones and S_1 spaced; clones and PX spaced and seeded; and S_1 and PX spaced. When S_1 and PX spaced were compared with PX seeded, both positive and negative non-significant correlations were obtained.

Parent-progeny relationships for characteristics other than yield have been less variable. Meyers and Chilton (11) obtained r values for winter survival between clones and S_1 progenies of 0.90 and 0.85 for orchardgrass and timothy, respectively. Weiss, *et al.* (15) found winter survival of orchardgrass clones was significantly correlated with OP progenies. Also in orchardgrass, Kalton, *et al.* (6) reported S_0 plants, S_1 plants, and S_2 family means were significantly correlated for leaf width and maturity. Tysdal and Crandall (13) reported the following correlations for bacterial wilt: *(1)* PX vs. S_1, 0.80 (14 df) and *(2)* PX vs. clone, 0.38 (44 df). Also for leaf hopper yellowing, the r value was 0.59 with 33 df for clones and the PX progenies. With ladino clover, Brigham and Wilsie (1) reported highly significant correlations of r = 0.84 with 8 df between seed setting of clones and the OP progenies and r = 0.92 for clones and the SC progenies.

Johnson and Hoover (5) found the predicted yields for OP performance in fair agreement with Syn 1 yields synthesized from intercrossing selected S_1 plants. Of 4 groups tested, the high yielding group and low yielding group reacted as expected. However, the medium low group produced a synthetic with higher yields than the medium high group. This was attributed to differences in combining ability.

Interseasonal- and interannual-variety interactions often confound the genetic differences and limit the predictive value of progeny tests. Correlations ranging from significantly negative to significantly positive have been reported (6, 10, and 15).

MATERIALS AND METHODS

The data were from 3 nurseries as follows: *(1)* space-planted clonal nursery, *(2)* space-planted progeny nursery with paired rows of S_1 and PX progenies, and *(3)* a seeded PX nursery.

In May, 1948, 225 clonal lines were transplanted into the field for further evaluation and production of PX seed. The nursery consisted of 6 replications in a 15 by 15 triple lattice design to obtain a random distribution of pollen. The rows had 8 plants of each clone in each replication, giving a total of 48 plants. Plants were spaced 18 inches apart in rows 40 inches apart. Green weight of forage was obtained for the first harvest in 1949, but the second growth was allowed to produce PX seed. Vigor was estimated May 12 and June 20, 1949. Selfed seed from 61 selected clones was obtained in the greenhouse in the winter of 1949–50. These seed together with PX seed of the same 61 lines, plus Ranger, Buffalo and Atlantic checks were seeded in greenhouse flats and the plants transplanted to the field in May 1950 with 4 replications in an 8 by 8 simple lattice. The S_1 and PX progeny rows were paired at random for each entry. The 10 plant rows were 40 inches apart with plants within rows 40 inches. A total of 40 plants of each PX and 40 of each S_1 progeny was transplanted. Some plants were lost during transplanting and a large number was lost in some lines during the winter of 1950–51. Consequently, all data were calculated on a per plant basis.

An estimate of total yield was made by scoring the most vigorous plant as 1 and the least vigorous as 9. These vigor ratings were used since analysis of yield data vs. vigor ratings in the clonal nursery had given significant correlation coefficients. The rating of H. H. Kramer with yield was 0.893 and the rating of R. L. Davis with yield was 0.897. Also the r values of the ratings of H. H. Kramer and those made by R. L. Davis was 0.917. Vigor ratings were recorded on May 1951, May 1952, June 1952, and April 1953. Green weights were taken on individual plants in June, July, and September, 1951.

Pseudopeziza leafspot ratings were made as described by Davis (2). Blooming indices and seed set were scored visually. Percent stand was the number of plants remaining August 1953 compared to the number surviving the transplanting in 1950.

On the basis of the clonal data, PX seed was harvested from 117 of the 225 clones. These, plus 7 check varieties, were seeded in rows 18 feet long and 40 inches apart. The nursery was seeded in April 1950 with 4 replications in a 11 by 11 simple lattice. The seeded area was on a new farm on recently tiled land and one replication was partly destroyed by excess water. Only 3 replications were used in the computations. Three hay harvests were taken in 1951 and 1952 and 2 in 1953. Blooming indices and seed set were recorded on the third harvest in 1953. Stands were calculated by counting the missing units (6 inch gaps) as suggested by Kramer and Davis (7).

[4] *Op. cit.*

The three 4-clone synthetics were seeded May 1952 in 4-row plots 1 foot apart and plots 27 feet long. The nursery was harvested 3 times each year and recorded as tons per acre at 12% moisture.

RESULTS

Yield Relationship Between Clones and Progeny

The yield relationship between the parental clones and both the S_1 and PX progenies as measured by correlation coefficients is presented in table 1. The r values were larger for the parent-S_1 progeny when yields were measured by both vigor ratings and green weight of harvested forage. However, the correlation of the parents with the S_1 progenies was significantly different from the same correlation with the spaced PX progenies only for the green weight measurement. Only one year's data were available for this computation. The correlation coefficient of 0.47 between the clones and the seeded PX progenies was significant even though the clones were in a space-planted nursery and the PX progenies were in a seeded-row nursery.

Yield Relationship Among Progenies

The correlation coefficients of the various clonal progenies are given in table 2. When the vigor rating of the plants was the yield criterion, the r value of 0.56 between S_1 and PX progenies in the spaced nursery was highly sig-

Table 1.—Correlation coefficients of parental clones and progeny yields.

Characters correlated	df	Correlation coefficients
Vigor ratings		
Parent clones and		
S_1's (3 year ave.)	57	0.47**
Spaced PX (3 year ave.)	57	.43**
Green cut		
Parent clones and		
S_1's 1951	58	0.56**
Spaced PX 1951	58	.32*
Seeded PX (3 year ave.)	112	.47**

* Significant at the 5% level.
** Significant at the 1% level.

Table 2.—Yield relationship of various progenies as measured by correlation coefficients.

Characters correlated	df	Correlation coefficients
S_1's rated (3 year ave.) and		
Spaced PX rated (3 year ave.)	59	0.56**
Seeded PX green cut (3-year ave.)	57	.22
S_1's green cut (1951) and		
Spaced PX green cut (1951)	60	.26*
Seeded PX green cut (1951)	58	.12
Spaced PX rated (3-year ave.) and		
Seeded PX green cut (3-year ave.)	57	.50**

* Significant at the 5% level.
** Significant at the 1% level.

Table 3.—Correlation coefficients of progeny yields in 1951 with those in 1952.

Characters correlated	df	Correlation coefficients
S_1's rated (1951) and S_1's rated (1952)	62	0.61**
Spaced PX rated (1951) and Spaced PX rated (1952)	62	.66**
Seeded PX green cut (1951) Seeded PX green cut (1952)	119	.69**

** Significant at the 1% level.

nificant. When the same S_1 progenies were correlated with the PX progenies in the seeded nursery, $r = 0.22$ was not significant. But these PX progenies differed from the S_1's in measurement of yield and in method of planting. However, when the S_1's and PX's differed only by method of planting, S_1 green cut vs. seeded PX, $r = 0.12$ was still not significant. Furthermore, the PX progenies rated in the space-planted nursery compared with the same PX progenies seeded and measured by green-cut harvested, gave a correlation coefficient of 0.50 which was highly significant. The lack of significant association was attributed to the method of planting. In the spaced nursery, the weak, non-vigorous plants had a much better chance of surviving in both the S_1 and PX progenies. However, a larger percentage of such plants would be found in the S_1 populations. In contrast, such non-vigorous plants could be eliminated in the row seedings (14). The greater proportion of such non-vigorous plants in the S_1 spaced population would reduce the total correlation value between the S_1 spaced and seeded polycross.

Genetic-environmental interactions are important in measuring genetic relationships. Even though the correlation coefficients were highly significant for 1951 vs. 1952 yield data, only 36 to 40% of the genetic variation could be accounted for (table 3). The r value 0.69 for the harvested yields was only slightly higher than the 0.61 and 0.66 for the estimated yields.

Correlation Coefficients for Characteristics Other Than Yield

Clonal and progeny relationship for factors other than yield are of paramount importance in estimating the efficiency of various methods of progeny testing. The r value of 0.79 for the association of clones and S_1 progenies for leafspot appeared to be slightly higher than the 0.76 for the clone vs. PX (table 4). This relationship was similar for the leafhopper yellowing measurements of $r = 0.44$ and 0.31 for S_1 and PX, respectively, even though the r values for the leafspot measurements were higher than those for leafhopper yellowing. As expected, the values for the S_1's vs. PX progenies were highly significant for both *Pseudopeziza* (0.91) and leafhopper yellowing (0.80).

The correlation coefficients for certain agronomic characteristics are recorded in table 5. Since good seed production is a prerequisite of every alfalfa variety and since seed production can not be measured with certainty every year in the breeding nursery, the relationship between blooming indices and seed set was recorded. The r values between

Table 4.—Correlation coefficients of disease and insect ratings of parental clones and progenies.

Characters correlated	df	Correlation coefficients
Pseudopeziza leafspot of clones and		
Rating of S_1's	59	0.79**
Rating of PX (spaced)	59	.76**
Pseudepeziza leafspot of PX (spaced) and Rating of S_1's	59	.91**
Leafhopper yellowing of clones and		
Rating of S_1's	59	.44**
Rating of PX (spaced)	59	.31*
Leafhopper yellowing of PX and Rating of S_1's	59	.80**

* Significant at the 5% level.
** Significant at 1% level.

Table 5.—Correlation coefficients of morphological and agronomic characters.

Characters correlated	df	Correlation coefficients
Blooming indicies PX (spaced) and		
Seed set PX (spaced)	62	0.44**
Blooming indicies S_1's	62	.65**
Blooming indicies PX (seeded) and Seed set of PX	119	.66**
Blloming indicies of S_1's and Seed set of S_1's	62	.21
Seed set of PX (spaced) and Seed set of S_1's	62	.38**
Percent stand PX (spaced) and Percent stand PX (seeded)	58	.54

* Significant at the 5% level.
** Significant at the 1% level.

blooming indices and seed set for 62 df was 0.44 in the spaced nursery and for 119 df was 0.67 in the seeded nursery. Also there was a significant r value of 0.65 between blooming indices of the S_1's and PX's. However, the seed set of the S_1's could not be predicted from the blooming indices, ($r = 0.21$) but the seed set of the S_1's and PX's was significantly correlated ($r = 0.38$).

Various measurements of stand and yield have suggested that 75 to 85% of the yield differences in alfalfa could be attributed to differences in stand. The r value of 0.54 for spaced vs. seeded suggests that a good stand estimate could be made in a spaced PX nursery.

Synthetic Yields

The yields of three 4-clone synthetics were compared with average clonal yields of the 4 lines constituting the synthetic and seeded PX progeny yields of these lines (table 6).

It is evident that the synthetic yields could not be predicted from clonal performance. Synthetic B, composed of plants having the highest clonal yield, produced the lowest yielding synthetic. However, the yields of the synthetic could be predicted from the PX progeny yields. Synthetic

Table 6.—Comparison of synthetic yields with the clonal and PX yields of composited lines.

Synthetic*	Clonal yield per plant 1949	PX yields per row 3-yr. ave.	Synthetic yield per acre 2-yr.ave.
	lbs.	lbs.	tons
A	1.38	18.0	4.33
B	1.41	14.9	3.76
C	1.27	18.2	4.59

* Four-clone synthetics.

Table 7.—Theoretical progeny values of clones, S_1's and PX's for a dihybrid.

Genotype of clone	Value in units		
	Clonal	S_1 progeny	PX progeny
AABB	16	16	13.0
AABb	13	13	11.5
AAbb	10	10	10.0
AaBB	13	13	11.5
AaBb	10	10	10.0
Aabb	7	7	8.5
aaBB	10	10	10.0
aaBb	7	7	8.5
aabb	4	4	7.0

C with the highest PX progeny produced the most forage in the synthetic combinations, whereas, Synthetic B with the lowest PX yields had the lowest synthetic yields. The other combination was intermediate in both PX and synthetic production.

DISCUSSION AND CONCLUSION

The correlation coefficients for all characters studied were higher for the clone vs. S_1 than for the clone vs. PX. This was expected from the theoretical distribution of genotypes presented in table 7 assuming additive gene action, non-dominance, and no epistasis. The genetic correlation coefficients for both the S_1 and PX values in table 7 were 1. However, the range of theoretical values for the PX progenies is 50% as much as the clones or S_1 progenies. Any genetic-environmental interactions would tend to reduce the phenotypic correlations of the clone and PX more than the clone and S_1. This was observed in all comparisons studied.

Clones, or individual plants as such, can be satisfactorily evaluated for some characteristics such as disease and some morphological characters. However, the critical test is the prepotency of the clones. Data presented showed that both S_1 and PX progenies were significantly correlated with the clonal values for all characters evaluated. Also when similar methods of culture were used, the S_1 and PX progenies were correlated. This suggests that if PX seed cannot be produced, then the S_1 progeny could be used to estimate the prepotency of the clone in a breeding program.

Even though the clones *per se* could have been used for leafspot evaluations, and possibly stand and blooming indices, the progeny test was essential for compositing the synthetics.

Tysdal and Kiesselbach (14) suggested the polycross progeny test for predicting the prepotency of clones. They suggested selecting self-incompatible plants to force cross-pollination and give a better measure of general combining ability. However, Wilsie (16) found no significant correlations between the self-compatibility and yield of the polycross progeny. Environmental conditions in areas having intensive breeding programs often limit or prohibit the production of polycross seed. Adequate selfed seed for a progeny test can be obtained from clones in the greenhouse. The S_1 progeny gave a better predictive value of the clone than the polycross progeny for all characteristics compared in this paper.

Considering all the facts on progeny testing, the following approach is suggested for alfalfa:

1. Self the obviously superior plants, e.g., those resistant to various diseases and insects.
2. Transplant 50 or more S_1 plants of each line using at least 10 replications.
3. Evaluate for all characteristics.
4. Eliminate the undesirable lines and the inferior plants within the more desirable lines. Allow the remaining plants to inter-pollinate and harvest polycross seed from the selected S_1 plants.
5. Use the results of the polycross progeny test to combine desirable clonal lines into synthetics.

SUMMARY

Parent-progeny correlation coefficients were presented for yield, diseases, insects, and various agronomic characteristics. The clones and S_1's were in a space planted nursery; and the polycross progenies were in both a space-planted nursery and a seeded row nursery. All the correlation coefficients calculated for clones and S_1 progenies and clones and polycross progenies were significant. However, the r values for clones vs. S_1 progenies were always higher than those for clones vs. polycross progenies.

The correlation coefficients for yield between the S_1 progenies and polycross progenies were significant when similar methods of planting were used. However, the yields in the spaced polycross nursery were significantly correlated with the yields in the row-seeded polycross nursery.

Correlation coefficients for yield values from both the spaced and seeded progeny nurseries in 1951 were significantly correlated with the yield values in the same nurseries in 1952.

Theoretical distributions of values of clonal, S_1 progenies, and polycross progenies were presented and the relation to the observed values was discussed.

Considering all the data on progeny testing, a breeding approach for alfalfa is suggested.

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Hygroscopic Equilibrium and Viability of Naturally and Artificially Dried Seed of Crimson Clover, *Trifolium incarnatum*[1]

H. S. Ward, Jr. and J. L. Butt[2]

INCREASED production of pasture and forage crops in the Southeastern United States has been accompanied by a corresponding rise in harvesting, processing, and storage of seed from these crops. If seed of high viability are planted, it is necessary to know how to cure and store these seed. Little is known concerning the behavior of seed during curing and storage under Southeastern climatic conditions.

Research pertaining to curing and storing seed was begun in 1947 at the Alabama Polytechnic Institute Agricultural Experiment Station, with some results being published in 1950 (1). This paper presents data on the hygroscopic equilibrium of the Auburn Reseeding Strain of crimson clover (*Trifolium incarnatum* L.) and its relationship to the viability of naturally and artificially dried seed.

Several workers have shown the importance of the hygroscopic equilibrium curves in determining behavior of seed during curing and storage (1, 2, 9, 11). Hygroscopic equilibrium data may be used to show the following:

1. The seed moisture content expected after curing in a known atmospheric relative humidity.
2. The relative humidity of the air contacting the seed of a known moisture content.
3. The changes in seed moisture content with fluctuations in relative humidity of the surrounding atmosphere.
4. The critical seed moisture content and the corresponding relative humidity for maintaining seed viability during storage can be predicted from the hygroscopic equilibria accompanied by germination data.

[1] Contribution from the Departments of Botany and Plant Pathology and Agricultural Engineering, Alabama Polytechnic Institute, Agricultural Experiment Station, Auburn, Ala. Published with the approval of the director. Received Aug. 13, 1955.

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Curves of the hygroscopic equilibria of various crop seed were summarized by Stahl (11). A recent review of the literature was given by Oxley (9), and by Brewer and Butt (1). According to these workers, the curves obtained by plotting hygroscopic equilibrium data from 0 to 100% relative humidities were of the sigmoid type, although they state that some workers have considered their curves to be parabolic. Parabolic curves were obtained of data that omitted the lowest humidities, and thus made an interpretation of direction of curvature difficult.

The interrelationship of hygroscopic moisture and its equilibrium relative humidity as related to mold development on seed has been reviewed by Gilman and Semeniuk (4). Organic substrates, such as textiles, feed, and seed that contain hygroscopic moistures in equilibrium with 75% relative humidities and above, have been shown to be susceptible to mold deterioration (8, 3).

Studies with wheat in bulk storage have established that the relative humidity of the interstitial air was dependent on the moisture content of the wheat (5, 6). The expected air-seed equilibria reached in bulk storage can be predicted from hygroscopic equilibrium curves for a particular seed. Such curves can be used as a guide in storing seed at moisture contents that result in interstitial relative humidities below that required for mold development. At such moisture contents, losses in germinability are at a minimum.

PROCEDURE

Crimson clover seed of the Auburn Strain, combine harvested in May 1950, were used in these studies. Hygroscopic equilibrium curves were based on data obtained by the methods of saturated salt solutions and the electric hygrometer (1). In the saturated salt solutions method, the seed were suspended over the salt solutions in shallow screenwire baskets. Seed and salt solutions were enclosed in sealed glass desiccators. The relative humidities of atmospheres in contact with saturated solutions of various salts

Table 1.—Relative humidities of atmospheres in contact with saturated solutions of various salts at 25° C.

Salt	Percent relative humidity
Ammonium dihydrogen orthophosphate	92.9
Potassium chromate	86.5
Ammonium sulfate	80.1
Sodium chloride	75.5
Sodium nitrite	64.8
Sodium diochromate dihydrate	54.1
Potassium carbonate	43.9
Magnesium chloride hexahydrate	32.9
Potassium acetate	22.9
Lithium chloride	11.1

at 25° C. are given in table 1. The storage chambers were kept in temperature-controlled cabinets at 25° C. In the electric hygrometer method, samples of crimson clover seed of different moisture contents were held in a moisture-tight box until equilibrium moistures were reached between seed and air. The relative humidities in equilibrium with crimson clover seed of different moisture contents were measured by the electric hygrometer. Brockington *et al.* (2) used a similar electric hygrometer.

Final moistures for crimson clover seed over the saturated salt solutions were obtained after a 2-month period and from the electric hygrometer in 24 to 72 hours. Moisture percentages on a wet weight basis of the seed were determined by drying the seed to a constant weight in a forced-draft oven at 105° C.

To show the effects of the various relative humidities on viability, combined crimson clover seed were dried naturally in the sun and artificially at 43.3° C. in a forced draft oven to 10.0% moisture. Subsamples of 200 g. from seed that were dried by the two methods were placed in chambers maintained by saturated salt solutions at relative humidities of 92, 86, 80, 75, 65, and 54%. Samples for germination were withdrawn at 6-, 9-, and 16-week intervals. The samples were stored until June 1953 at 65 and 54% relative humidities. They were taken for germination tests after storage for 12-, 24-, and 36-month periods. The humidity chambers were not held under constant temperature conditions but were stored under laboratory conditions at temperatures not exceeding 35° C. during the summer and not less than 20° C. during the winter.

All tests of viability of the crimson clover seed were made by placing quadruplicate 100-seed samples between blotter substrata in a germinator held at 20° C. Germination and hard seed counts were made at the end of a 7-day period.

RESULTS

Hygroscopic Equilibria of Crimson Clover Seed

The hygroscopic equilibrium curve for the crimson clover seed at the end of 8 weeks of storage over various saturated salt solutions is shown in figure 1. Increases of relative humidity within the range of 65 to 100% caused a sharp rise in the hygroscopic moisture of the crimson clover seed. As the hygroscopic moisture increased, metabolic activity within the seed increased. Moreover, the higher water vapors surrounding the seed were probably conducive to mold development. Mold growth and metabolic activity in the seed caused a rise in temperature. Losses in germinability occurred after 8 weeks storage at relative humidities above 65%. In contrast, changes in relative humidity from 65 to 10% caused only small differences in hygroscopic moistures of the seed. This is shown by the slope of the curve within this range.

The hygroscopic equilibrium curve plotted from the electric hygrometer data is presented in figure 2. The relationships established for the curve by the method of saturated salt solutions were similar to the electric hygrometer curve. The main discrepancies were in the higher hygroscopic moistures. A comparison of the two curves is shown in figure 3.

Germinability of Naturally and Artificially Cured Seed

Differences in germination and percentage of hard seed of naturally and artificially cured crimson clover seed after storage at various humidity levels for 6-, 9-, and 16-week intervals are shown in figure 4. The method of curing caused only small differences in germination and percentage of hard seed. Instead, the relative humidity and duration of storage determined loss in germination by the crimson clover seed. Loss in viability occurred at all storage humidities above 65%. Losses in germination occurred more rapidly as the storage humidity increased.

At the 65 and 54% storage humidities, germinations did not decline after 16 weeks. The apparent reduction in viability at 6- and 9-week intervals was thought to be a dormancy effect. Thus, the data in figure 4 show that storage of 6 weeks at humidities of 92 and 86% caused a decline in

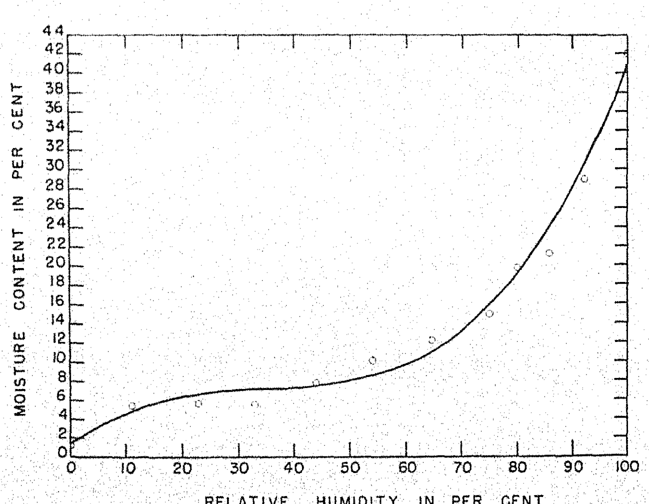

Fig. 1.—Hygroscopic equilibrium curve for crimson clover seed determined by the method of saturated salt solutions.

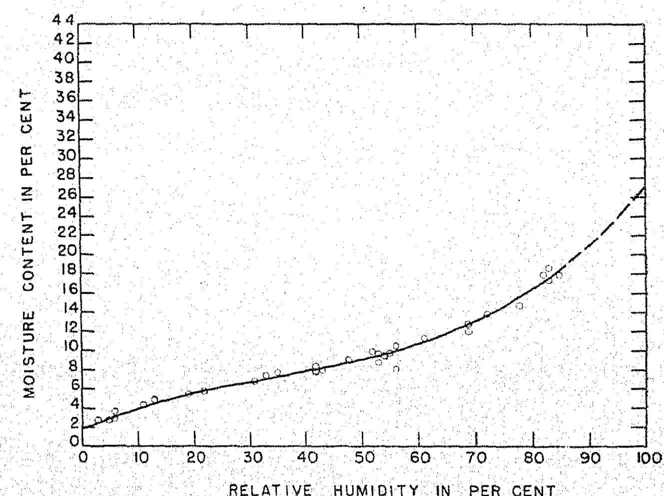

Fig. 2.—Hygroscopic equilibrium curve for crimson clover seed determined by the method of the electric hygrometer.

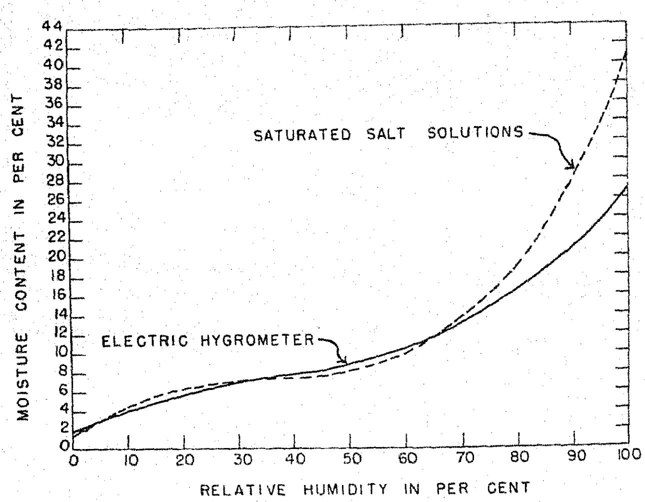

FIG. 3.—Hygroscopic equilibrium curves for crimson clover seed determined by the methods of saturated salt solutions and electric hygrometer.

germinability to less than 10%. With a decrease in humidity to 80% after 6 weeks of storage, germinability was approximately 35%, but after 9 weeks it was less than 10%. Less reduction in germination occurred at a storage humidity of 75%, but the loss was too high to consider for storage.

For storage periods of 4 months or less, losses in germination of combined crimson clover seed can be prevented when the seed are stored at hygroscopic moistures of 12.3% or lower (in equilibrium with 65% relative humidity). This inference is drawn from the data in figure 5. The data further showed that, at 10.1% hygroscopic moisture (in equilibrium with 54% relative humidity), germination was slightly higher than seed at 12.3% moisture. For storage of longer than 4 months, seed with a moisture content of 10.1% were required to prevent a decline in germination. The trends in germination for a 36-month storage period at 65 and 54% storage humidities (hygroscopic moistures of 12.3 and 10.1%, respectively, are presented in figure 6.

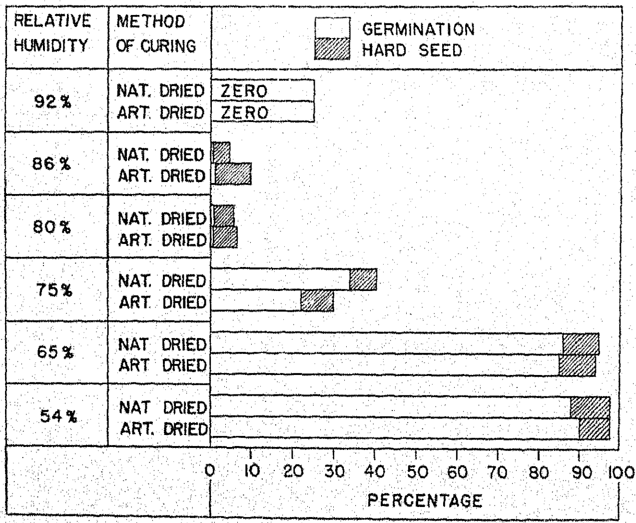

FIG. 5.—Germinabilities and hard seed of naturally and artificially dried crimson clover seed stored at various relative humidities at the end of 16 weeks.

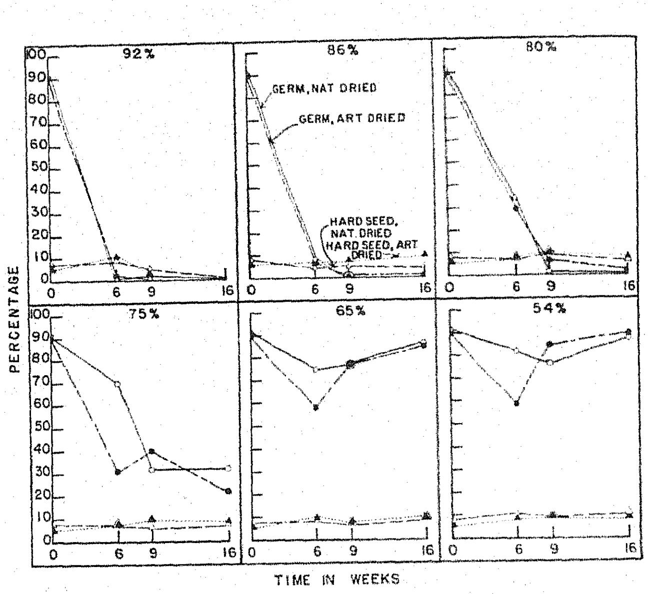

FIG. 4.—Germinabilities and hard seed of naturally and artificially dried crimson clover seed stored at various relative humidities at 6-, 9-, and 16-week intervals.

DISCUSSION

Results from the determination of the hygroscopic equilibrium curves of crimson clover seed by the saturated salt solutions and the electric hygrometer methods were in essential agreement except at the higher hygroscopic seed moistures. One of the causes for divergence of the crimson clover seed curves was that the equilibrium moistures of the electric hygrometer curve were extrapolated at relative humidities above 85% (see figure 2). These deviations at the higher hygroscopic moistures were not found for blue lupine seed by Brewer and Butt (1). Their equilibrium data by the electric hygrometer method were obtained at relative humidities up to 98%, and this permitted a plotting of the exact direction of curvature at the higher equilibrium seed moistures. Another possible cause for deviations of these curves was that the equilibrium data at relative humidities above 54% obtained over the saturated salt solutions represented an absorption of moisture, while the equilibrium data obtained by the electric hygrometer represented desorption

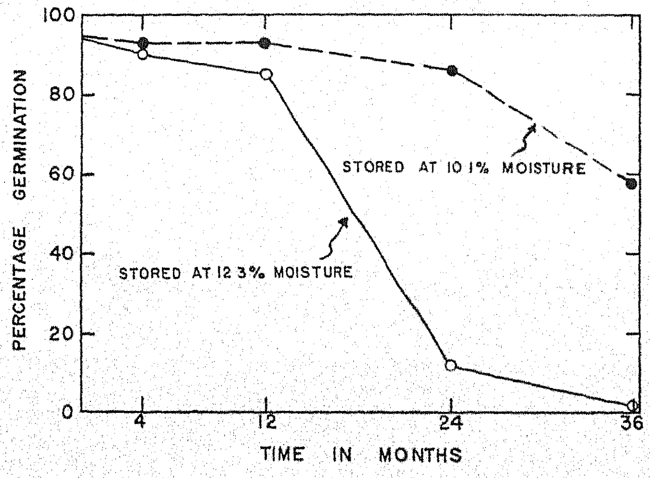

FIG. 6.—Germinabilities of crimson clover seed stored at 10.1 and 12.3% moisture contents at 4-, 12-, 24-, and 36-month intervals.

of moisture. At relative humidities below 54%, the equilibrium data obtained over the saturated salt solutions were a desorption curve, while the equilibrium data by the electric hygrometer represent an absorption curve. This is an example of the hysteresis phenomenon.

Despite the differences referred to, computation of regression equations for the best-fitting curves by the method of least squares (10) showed that the curve in each case was of the sigmoid type represented by curves of the third degree ($Y = a + bX + cX^2 + dX^3$, where Y = seed moisture and X = relative humidity). Parabolic equations do not agree well with the data. The sigmoid curve agrees with that of Oxley (9) and Brewer and Butt (1). Data summarized by Stahl (11) show that others have obtained curves of the parabolic type. The regression equations for crimson clover seed are presented below:

Saturated salt solutions (figure 1) – $Y = 1.1978 + 0.47228X - 0.012661X^2 + 0.0011879X^3$.

Electric hygrometer (figure 2) – $Y = 1.6849 + 0.26987X - 0.0047838X^2 + 0.00046237X^3$.

As previously stated, decreases in hygroscopic moisture in crimson clover seed caused a corresponding increase in the time of decline in viability. One of the main causes for losses in viability of crimson clover seed stored in equilibrium with relative humidities of 75% and higher may be attributed to the development of a fungal population. Fungal growth could kill the seed by heat resulting from respiratory activity, destruction of the cell walls by pectinase enzymes, and unknown toxic substances. This is in agreement with other investigations of seed (3, 4, 8) where fungal growth was obtained at seed hygroscopic moisture contents in equilibrium with 75% relative humidities or higher.

Results of the germination studies in relation to various storage relative humidities and seed hygroscopic moistures point to the value of obtaining the basic hygroscopic equilibrium curve for predicting seed behavior during storage. The important implication, however, is not primarily one of obtaining hygroscopic seed moistures but also the relative humidities in equilibrium with hygroscopic moistures. The relative humidity of the air surrounding the seed determines a fungal population build-up with the subsequent effects on seed deterioration and loss in viability. This humidity is determined by the moisture content of the stored seed. Safe storage of seed is a function of the relative humidity in equilibrium with seed rather than the moisture content of the seed.

SUMMARY

The hygroscopic equilibrium curve for combined seed of the Auburn Strain of reseeding crimson clover was determined by the methods of saturated salt solutions and electric hygrometer. The formulae of the curves were computed from data by the method of least squares and shown to be of the sigmoid type.

The rate of loss in germinability of crimson clover seed when stored for a 4-month period was found to be proportional to increased relative humidities. Germination declined only slightly after 4 months at a storage relative humidity of 65% (12.3% moisture) and no loss occurred at 54% relative humidity (10.1% moisture). A hygrocopic moisture content not exceeding 12.3% is recommended for the storage of crimson clover seed for periods of not more than 4 months. For storage of more than 4 months and for as long as 24 months, a hygroscopic moisture not exceeding 10.1% is recommended.

The number of hard seed was not affected by storage relative humidities at 86% or less. At a relative humidity of 92% the number of hard seed was reduced to zero.

The method of curing either by natural drying or artificial heat (43.3° C.) to a hygroscopic moisture content of 10.0% did not effect the response of the crimson clover seed to the various storage relative humidities either in respect to germinability or hard seed.

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Intra-inbred Line Variation in Resistance to a *Pythium* Seedling Disease of Corn[1]

A. L. Hooker[2]

THE many factors associated with poor stands when corn is planted in cold, wet soils have been discussed in recent papers.[3 4 5] Satisfactory stands under these conditions rest largely on the ability of the seed to resist or to be protected from soil-borne parasitic microorganisms. The present investigation was made to determine the range of variability among individual ears and ear selections, within several dent corn inbred strains, with respect to this resistance.

MATERIALS AND METHODS

Five inbred strains of dent corn (A375, M14, W16, W23, and W28) were selected initially for this study. These strains represented a range of maturities and varied in their relative ability to produce good seedling stands when planted in a cold, wet soil infested with a complex of microorganisms. Each had been self-pollinated for a minimum of 18 generations, with occasional sib-pollinations between ear selections.

Progenies were grown in the field in 1948, 1949, 1950, and 1951 in rows consisting of ten or twelve 2-plant hills. As many plants as possible in each were self-pollinated. Ears were harvested at maturity (preharvest frost in 1950 and 1951), dried at 105° F. with forced air circulation and stored in a cool dry room until tested.

The testing procedure, hereafter referred to as the cold soil test, involved the following classes of seed: *(1)* uninjured, hand shelled seed; *(2)* injured, seed with pericarp injured by shaking it in a roughened container; and *(3)* treated, uninjured seed dusted with a fungicide (thiram). Throughout the experiment, self-pollinated seed was evaluated on an individual ear basis. Each year the three classes of seed were planted in a parallel series and all ears of a given inbred strain were evaluated simultaneously in a single test. A completely randomized experimental design was used with 3 replications of 10 kernels from each ear for each class of seed. The seed was planted in pans of muck soil, known to be infested with *Pythium debaryanum* Hesse and *P. ultimum* Trow, both species having proved highly pathogenic to corn kernels in cold soil. The soil was moistened to approximately 60% of water holding capacity, kept for 14 days in a cold chamber maintained at 11° C., and then moved to a warm room for seedling development. Records were taken at the 3-leaf stage and a disease resistance index, equivalent to a weighted germination percentage, was calculated for each entry. This index was obtained by the summation of assigned arithmetical values of 4 to each healthy seedling, 3 to each stunted seedling with a healthy root system, 2 to each stunted seedling with a lesioned root system, and 1 to each seedling blighted before emergence. Thus, with three 10-kernel replicates, the lowest total index value for an ear with each class of seed was 30 and the highest 120.

In 1948, 8 rows were planted from a composite of hand pollinated seed of each inbred strain. Plants were self-pollinated, and in the following winter about 200 of the earliest pollinated ears were evaluated individually in the cold soil test. On the basis of these tests, 83 ears were selected, representing low, intermediate, and high disease index classes within each inbred, and used for ear-row progeny plantings in 1949. Again self-pollinations were made in each progeny providing more than 1,500 ears for the cold soil test. In 1950, progeny plantings were made from 80 selected ears representing high and low disease index classes within 16 progenies grown in 1949. In addition, as all previous progenies originated from bulk lots of hand pollinated seed, a comparative group of 11 ear-row progenies of inbred W3, with known parentage for 22 generations, were grown in 1950. About 1,100 self-pollinated ears were produced for individual testing. In 1951, progeny plantings were made from ears of representative high, intermediate, and low index classes within each inbred strain and self-pollinated ears were tested the following winter.

EXPERIMENTAL RESULTS

All inbred strains showed a similar response to the procedures employed in this study. As an illustration, summarized data for uninjured and injured seed of inbred W28 are presented in table 1. Data for treated seed, data for inbreds A375, M14, W3, W16, and W23, and the statistical analyses of all strains can be found elsewhere.[6]

In the 1948 cold soil tests, statistically significant differences in resistance indices were obtained among individual ears within each inbred strain, the magnitudes of which varied with the inbred and with the class of seed. Though large differences attributable to the three classes of seed were measured, the ranking of ears was similar in each. Laboratory germination tests conducted at room temperature indicated only minor differences in the germination capacity of seed from these ears. Likewise, the prevalence and type of seed-borne organisms, although varying considerably with the inbred, afforded little evidence to explain the differences in reaction. A progeny test was made in 1949 to determine if genetic differences existed among these ears.

Differences in index values among ear-progenies of inbred W28, as well as of other lines grown in 1949, were highly significant. These reactions were closely associated with that of their parent ears as indicated by positive and statistically significant correlation coefficients between parent and progeny reactions for each inbred strain and by the highly significant correlation coefficient of +0.541 over all strains. The data indicated that selection was effective in isolating sub-lines differing in their ability to produce satisfactory seedling stands in *Pythium* infested soil at low temperatures.

Highly significant differences in index values in the cold soil test were measured among individual ears within progenies 77, 78, 79, 81, and 83 of inbred W28 and within 90% of the remaining sub-lines so studied and grown in 1949. However, only 4 out of the 16 sets of progenies grown in 1950 from contrasting ears of these sub-lines differed significantly in their reaction in the cold soil test. In 2 of these cases, including progenies 170–173 of inbred

[1] Contribution from the Departments of Plant pathology and Agronomy, University of Wisconsin, Madison, Wis. Published with the approval of the Director of the Wisconsin Agricultural Experiment Station. Received Aug. 24, 1955.

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W28, these differences were not in the direction expected if selection were effective. Selection appeared to be effective in progenies 168 and 169 of inbred W28 but a retest from the same parent ears in 1950 (progenies 223 and 224) did not confirm this. Only in one case (M14) was selection apparently effective in 1949 and confirmed in 1950. For the most part, selection within a sub-line was ineffective.

When data for index values for the progenies grown in 1950 from ears of the same 1949 selection were pooled and an analysis of variance calculated, highly significant differences were evident for both inbreds W28 and M14. The differences in reaction among the 1949 selections, which were continued in 1950, also were highly significant. Correlation coefficients between the means of the 1950 progenies and the means of their parents grown in 1949, for inbreds W28 and M14, approached or exceeded the 5% level of significance. These data, and those for the progenies grown in 1951, indicated a strong tendency for differences in sublines to be maintained in later populations derived from them.

Differences beyond the 1% level of significance were measured in the cold soil test among the 11 progenies of inbred W3 grown in 1950. On the basis of their parentage, the progenies were grouped in various ways and analyses of variance calculated for data between, or among, these groups. Though significant differences were found in some of these comparisons, they showed little relationship to the pedigrees.

Progenies of all inbreds grown in 1949 from ears of low index classes averaged respectively 13.0 and 14.4 disease resistance units lower for injured and uninjured seed, than a comparable number of progenies from ears of high index classes. When a similar comparison was made between the average of progenies grown in 1950 from ears of low index classes within sub-lines, and the average of progenies grown from ears of high index classes, differences of only 2.5 and 1.5 disease resistance units respectively for injured and uninjured seed were measured.

The average mean squares for disease index values for progenies grown in 1948 was 146.8, the average for progenies grown in 1949 which were continued in 1950 was 90.3, and that for those grown in 1950 was 77.2, indicating that the amount of variability within progenies decreased as selection was continued. This decrease in variability may be due in part to the isolation and stabilization of sub-lines and in part to individual seasonal responses.

Table 1.—The field plan, pedigrees, number of ears tested in each progeny, mean index values, and standard deviation of parent populations and ear selections of inbred W28 grown and tested in the cold soil test for years indicated.

Year grown	Row no.	No. of ears tested	Parent number	Uninjured seed			Injured seed		
			row–ear	Index of parent	Mean index of progeny	s ±	Index of parent	Mean index of progeny	s ±
1948	5	25	——	—	57	12.8	—	47	10.5
1949	77	22	5–12	35	75	11.4	32	50	7.8
1949	78	18	5–19	49	74	7.9	38	50	6.1
1949	79	15	5– 7	44	90	4.3	34	50	5.8
1949	80	18	5–18	50	86	6.3	36	62	6.2
1949	81	20	5– 2	89	89	8.4	69	73	9.6
1949	82	16	5– 6	86	108	6.2	68	92	7.2
1949	83	21	5– 1	103	95	8.1	94	72	9.9
1950	137	20	77–21	48	70	11.6	35	58	9.9
1950	138	21	77–19	49	77	11.8	33	63	11.0
1950	139	19	77–16	106	61	11.1	55	51	12.3
1950	140	21	77– 3	116	70	15.7	64	58	12.5
1950	164	14	78–13	53	42	6.0	46	33	2.7
1950	165	11	78– 7	54	37	5.6	42	34	4.4
1950	166	17	78–17	96	43	6.9	49	36	4.0
1950	167	13	78– 9	96	40	5.4	53	34	3.0
1950	168	18	79– 1	74	41	6.0	60	34	2.0
1950	169	17	79– 7	99	79	12.2	65	68	10.4
1950	170	14	80– 5	67	94	10.8	53	86	11.1
1950	171	14	80–16	73	84	11.3	46	75	11.7
1950	172	14	80– 6	102	72	10.2	72	72	9.2
1950	173	13	80– 3	106	69	11.1	64	63	11.9
1950	174	10	81– 1	55	60	8.4	48	54	6.9
1950	175	11	81– 3	65	73	11.8	54	66	12.1
1950	176	15	81–20	117	72	13.7	87	68	12.1
1950	177	14	81– 6	113	78	8.9	92	73	7.8
1950	178	10	83–11	60	79	10.7	43	80	9.8
1950	180	12	83–16	113	83	7.9	84	80	8.7
1950	181	11	83– 6	110	70	11.4	104	66	9.9
1951	218	11	165–11	33	61	——	36	40	——
1951	219	17	168–14	44	62	——	30	48	——
1951	220	6	173–11	66	75	——	95	57	——
1951	221	11	177– 9	104	85	——	92	71	——
1951	222	8	180– 4	102	73	——	109	66	——
1951	223	14	79– 1	74	88	——	60	74	——
1951	224	16	79– 7	99	85	——	65	68	——

DISCUSSION

It appears that some long-time inbred strains may consist of a mixed population of sub-lines which differ in their reaction in the cold soil test. This could be anticipated if the inbred strains, as for those involved in this study, were maintained as a composite of several ear-row selections each generation. The data indicate that these inbred strains were heterogeneous rather than heterozygous for this character. It follows that inbred strains maintained by a single plant selection each generation probably would not show sub-line variation but could express ear or plant variation in the cold soil test. The former appears heritable while the latter is presumably due to environmental conditions.

The significant implication of sub-lines within an inbred strain is apparent in genetic studies on the inheritance of the cold soil test reaction and in other studies where genetically uniform seed is desired. Secondly, selecting the more resistant sub-lines for crossing offers a possibility of increasing the resistance of corn hybrids to fungi in cold soils, without necessarily altering other characteristics. Usually, selection is more effective between, rather than within, inbred strains; but in some special cases, selection within inbred strains may be effective. The number of these special cases may be increased with additional research along lines similar to those presented here.

SUMMARY

Significant differences in disease resistance index values were found among individual ears within five long-time inbred strains of dent corn evaluated in a cold soil test. Neither a laboratory germination test nor a determination of seed-borne disease organisms was sufficient to explain these differences. To ascertain if part of this variation was heritable, ears of low, intermediate, and high disease index classes, respectively, in each strain were selected for progeny testing. Significant differences were evident among the progenies grown from selected ears within each inbred strain. The means of these progenies were associated with the reaction of their parent ears. Selection appeared to be effective in isolating sub-lines which differed in their reaction in the cold soil test. Differences in reaction among individual ears within these sub-lines were found, but progeny tests indicated that these were non-heritable. There was a strong tendency for the differences in sub-lines to be maintained in populations grown from them.

Additional Seed Factors Affecting Stands of Corn in Cold Soils[1]

A. L. Hooker[2]

NUMEROUS factors affect corn seed germination and seedling development under adverse conditions. They can be divided into 2 general groups: those relating to the soil environment, including pathogens, and those concerned primarily with the seed. Many of these factors have been enumerated and discussed in recent papers (2, 4, 7). The present paper presents data on the effects of seasonal conditions, date of planting, plant population, and soil nitrogen level on the maternal plant, in predisposing seed to infections by *Pythium debaryanum* Hesse and other soil fungi at low temperatures.

1. SEASONAL INFLUENCES

Materials and Methods

The seasonal influence on the predisposition of seed to disease incited by soil fungi was studied by evaluating progeny plantings from 13 parent ears of 3 well established inbred lines (A375, M14, W23) in 3 successive seasons. Progenies were planted and harvested on May 8 and Oct. 15, 1949; May 12 and Sept. 30, 1950; and on May 10 and Oct. 15, 1951 respectively. Ears were dried at 105° F. with forced air circulation and stored in a cool dry room until tested. Each year three classes of selfed seed, involving untreated, mechanically injured, and treated with a fungicide (thiram) respectively, were evaluated on an individual ear basis in replicated tests for resistance to soil fungi. These evaluations were made by planting the seed in *Pythium*-infested soil, moistening to approximateley 60% of water holding capacity, incubating immediately at 11° C. for 14 days, and then moving to a warm room for seedling development. Weighted germination percentages were obtained using a uniform scale. Details of the testing procedure and method of obtaining the germination percentages are presented elsewhere[3] (3).

EXPERIMENTAL RESULTS

One hundred ninety-two individual ears were tested in 1949, 173 in 1950, and 146 in 1951. Untreated seed from these ears produced an average germination percentage of 65.6, 47.5, and 58.9% respectively in these 3 years. Mechanically injured seed was reduced in germination by approximately 25% while treatment with a fungicide increased germination by more than 50%.

Statistical analysis of the data showed a highly significant difference among seasons when the season mean square was tested against the mean square due to error or against the mean square due to the interaction of progenies × seasons × treatments. Likewise, the mean squares for progenies, treatments, progenies × seasons, and seasons × treatments were all significant at the 1% level.

Seasonal temperature and moisture conditions (table 1) at Madison, Wis., differed during the 1949, 1950, and

[1] Joint contribution from the Departments of Plant Pathology and Agronomy, University of Wisconsin, Madison, Wis., and the Department of Botany and Plant Pathology, Iowa State College, Ames, Iowa. Published with the approval of the Director of the Wisconsin Agr. Exp. Sta. Journal Paper No. J-2777 of the Iowa Agr. Exp. Sta., Ames, Iowa. Project No. 1140. Received Aug. 24, 1955.

[2] Agent (Plant Pathologist), Field Crops Research Branch, A.R.S., U.S.D.A., Madison, Wis.

[3] Hooker, A. L. Variation in heritability and nature of resistance to a Pythium seedling disease in corn, Ph.D. thesis. Univ. of Wisconsin. 1952.

Table 1.—Accumulated heat units and precipitation at Madison, Wis., from planting to harvest in 1949, 1950, and 1951.*

Month	Accumulated heat units†			Accumulated precipitation‡		
	1949	1950	1951	1949	1950	1951
May	172	207	273	1.92	2.21	2.61
June	800	707	699	8.35	8.46	5.16
July	1579	1317	1344	14.11	19.39	8.24
August	2263	1818	1869	16.31	22.08	11.32
September	2465	2145	2132	17.43	24.17	13.88
October	2610	2145	2219	19.04	24.17	14.76

* Data calculated from the U. S. Dept. Commerce, Weather Bureau, Climatological Data, Wis. section reports.

† Calculated from formula $\Sigma\ (\frac{\text{Daily maximum} + \text{Daily minimum}}{2} - 50.)$

‡ Inches of rainfall.

1951 growing seasons. High temperatures and ample rainfall prevailed in June, July, and August of 1949 followed by a cool and dry September and October. These conditions were favorable for corn production and average corn yields were high. Generally cool and wet conditions prevailed throughout 1950 and seed was harvested at the end of September to escape predicted freezing temperatures. The 1951 season resembled the 1949 season except for moisture and temperature distribution. Generally high temperatures and abundant moisture prevailed in May and September of 1951, but June, July, and August temperatures and rainfall were considerably below those prevailing for the same months in 1949.

The ranking of accumulated heat units for the three years (table 1) was in the same order as average germination percentage in the cold soil test.

II. DATE OF PLANTING SEED PARENT

Materials and Methods

Livingston (5) and Rush and Neal (6) have demonstrated that seed harvested at periodic intervals after pollination increased in resistance to soil fungi at low temperatures. In the present study, the influence of the seasonal environment on, and predisposition to disease was compared in self-pollinated ears harvested from early and late plantings. Nine previously tested ears of inbred W23 were selected and adjacent ear-to-row plantings made from each ear on May 9, and June 2, 1949. The long, favorable growing season at Madison in 1949 resulted in plants at both planting dates ripening to approximately the same moisture content, and all ears were harvested on the same day. A total of 237 ears from these 18 progenies were individually evaluated for resistance to fungi in cold soil employing the method previously described.

Experimental Results

The detailed data from these tests[4] are summarized in table 2. Seed from the 9 late planted rows was consistently

[4] Hooker, *op. cit.*

Table 2.—Mean germination percentages in cold soil of individual ear seed from paired early and late planted progenies of 9 parent ears.

Early or late planting	No. ears tested	Untreated seed	Injured seed	Treated seed
Early	136	73.2	64.2	94.3
Late	101	51.8	42.3	92.4

more susceptible to fungi in cold soil than seed from the 9 early planted rows. In the statistical analysis of the data, differences in stands and vigor between planting dates, among progenies, and the interaction of progenies × planting dates were highly significant. The largest portion of the variance was attributable to planting dates.

III. RATE OF PLANTING AND SOIL NITROGEN LEVEL

Materials and Methods

The influence of plant population and soil nitrogen level in predisposing seed to infections by soil fungi was studied by evaluating seed produced at population levels of 12,000, 16,000, and 20,000 plants per acre and at 0, 100, and 200 pounds nitrogen per acre. This seed was obtained from 15 open pollinated single hybrids grown near Clarion, Iowa, in 1953 under these conditions but with uniform levels of phosphorus and potassium.

The testing procedure consisted of planting 3 replications of the 135 seed lots between layers of steamed quartz sand mixed with young cultures of *P. debaryanum* Hesse over steamed soil in individual clay pots. The pots were then watered to approximately 60% of water holding capacity and incubated at 11° C. for 14 days. At the end of this period, the pots were moved to a warm greenhouse bench for seedling emergence. At the 3-leaf stage, the seedlings were washed free of soil and sand and separated into 6 classes depending upon germination and the severity of root lesioning. A weighted germination index was obtained using a uniform scale (2).

Experimental Results

Total germination indices for hybrids, levels of nitrogen, and plant population levels, over all treatments, are presented in table 3. Statistical analysis of the data showed that the variation due to hybrids was significant at the 1% level while the variations due to nitrogen levels, plant population levels, and all interactions were nonsignificant.

DISCUSSION

The ability of a slowly germinating corn kernel, in contact with parasitic soil microorganisms, to survive and pro-

Table 3.—Total germination indices of seed from 15 open pollinated hybrids grown near Clarion, Iowa at 3 levels of nitrogen and 3 levels of stand when tested for resistance to *Pythium debaryanum* at low temperatures.

Totals for Hybrids

Hybrid	Index	Hybrid	Index
WF9 × 187–2	577	WF9 × I205	890
187–2 × M14	695	187–2 × I205	945
187–2 × W22	702	OS420 × M14	948
W22 × M14	757	M14 × I205	1,058
WF9 × W22	768	OS420 × I205	1,103
WF9 × M14	771	OS420 × W22	1,141
OS420 × 187–2	830	W22 × I205	1,175
WF9 × OS420	887		

Totals for Nitrogen and Stand Levels

Pounds nitrogen per acre	Index	Number plants per acre	Index
0	4,405	12,000	4,430
100	4,438	16,000	4,318
200	4,404	20,000	4,499

duce a seedling is markedly affected by many factors in addition to genotype. The seed factors generally regarded as contributing to a reduction in germination under adverse conditions also cause, or they are associated with, an inferior or weakened condition of the seed. Many of these factors have been isolated and studied, but the relative importance of each, and the actual mechanism by which they affect germination under adverse conditions is not clear. Conceivably other environmental factors, as yet undetermined, may also affect seed germination under adverse conditions.

While the factors reported on in this study may not be of major importance, they are factors which affect seedling stands of corn under adverse conditions and merit attention. A consideration of them may shed some light on the variation encountered among seed lots of the same genotype produced in different years, or in different locations within the same year.

Throughout these studies, precautions were taken to minimize variation due to host genotype and to standardize the testing procedure for each study. When possible, direct comparisons were made among seed lots in the germination evaluations. When this could not be done, as in the seasonal test, precautions were taken to conduct the evaluations under conditions which were uniform for all seasons. Here variation attributable to seasonal conditions would be confounded with season to season variation in the test itself, but experience indicates that the latter was minor.

The seasonal data suggest a relationship between heat units and other environmental conditions during the growing season and resistance of the seed to soil fungi at low temperature. The seasonal germination, temperature, and moisture data indicate that temperature and moisture conditions which are generally regarded as the most favorable for growth and maturation of corn also tend to result in seed with good resistance to soil fungi in cold wet soils.

A delay of 3 weeks in spring planting postponed anthesis by only 1 week and both plantings produced seed of approximately the same moisture content at harvest. Although the early and delayed plantings were in adjacent rows, each was exposed to slightly different environmental conditions at comparable stages of growth due to the different planting dates. Seed from the delayed plantings consistently produced poorer stands in cold *Pythium* infested soil than did that from the early planted counterparts. Thus, delayed planting may cause effects similar to those resulting from different harvest dates. It would appear that this effect would be of importance in inheritance studies where delayed plantings are often employed in order to achieve the desired cross pollinations.

Level of soil nitrogen and number of plants per acre did not appear to influence the resistance of the seed to *Pythium* at low temperatures in these tests. The seed lots tested may not have been sufficiently representative to sample such effects, as they were all the same grade, although the grading percentage varied considerably among lots. However, the absence of these effects was consistent for all hybrids, while differences among hybrids in their resistance to *Pythium* at low temperatures were brought out. Genetically, these are largely associated with the seed parent as all plants were open pollinated.

The influences of planting date, seasonal conditions of temperature and moisture, seed maturity, preharvest frost, and artificial drying in predisposing the seed to *Pythium* infections may all be related. Little is known of the anatomical or physiological mechanisms in the germinating seed that determine whether the embryo will survive attacks from soil fungi, and still less is known as to how these mechanisms may be modified by certain environmental conditions. Seed permeability (7) and rate at which resistance to *Pythium* develops in the germinating embryo[5] (4) have been suggested as being associated with germination and seedling stands in cold soils. Excised embryos of the same genotype from mature seed have been shown to develop resistance to *Pythium* at a faster rate during germination than excised embryos from immature seed.[5] Histological studies[5] of excised embryos from resistant and susceptible strains artificially inoculated with *P. debaryanum* Hesse revealed a differential spread of the intracellular mycelium in the scutella of contrasting strains. In susceptible embryos, cells in advance of and adjacent to the mycelium were plasmolized and appeared dead. The mycelium spread extensively and apparently without limitations. In the scutella of resistant embryos, the spread of the mycelium was limited. A dark staining material accumulated in the intercellular spaces and on the cell walls adjacent to the infested region. Responses similar to these are common in roots and stems of many diseased plants, and these expressions in some plants have been associated with the availability of particular food reserves as well as the expression of various metabolic processes. Conceivably, environmental conditions which contribute to corn seed viability and quality strengthen these responses to fungus penetrations.

Whatever may be the environmental factors in predisposing seed, and their effects on stands of corn in cold soils, the seed parent is influenced to a larger degree than the pollen parent. A recognition of this is important in the planning and interpretation of genetic studies. These environmental effects may be associated with differences in reciprocal hybrids and the apparent major influence of the pistillate parent in crosses. Usually in an inheritance study, date of planting, time of pollination and date of harvest are largely determined by the characteristics of the seed parent. Frequently, individual ear shoots in the same progeny row are pollinated by several pollen parents. Under these conditions, any seed character, such as cold-test reaction, that is influenced by the environment during growth and maturation and by post harvest handling conditions would be more strongly modified in hybrids toward the characteristics of the seed parent rather than the pollen parent.

SUMMARY

The effects of seasonal conditions of temperature and moisture, date of planting, level of soil nitrogen, and plant population, on the predisposition of corn seed to infection by *Pythium debaryanum* and other soil fungi at low temperatures were studied. Seed produced in 1949 under warm temperatures and ample soil moisture during June, July, and August followed by a generally cool but dry September and October produced better stands than that produced in 1951 under generally cool and dry conditions or in 1950 under cool and wet conditions. Delayed planting resulted in seed with an increased susceptibility to soil fungi at low temperatures. No measurable differences

[5] Hooker, *op. cit.*

in resistance to *P. debaryanum* at 10° C. were detected among seed lots of the same genotype produced at three levels of soil nitrogen or at three levels of plant population.

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Terramycin and Plant Growth[1]

A. G. Norman[2]

THERE is now a substantial literature on the effects of antibiotics on the growth of plants or plant parts. In general, such compounds when applied to higher plants have been found to be either inhibitory or inactive, but there are scattered reports of growth stimulation. This is particularly the case with terramycin (oxytetracycline). Nickell (3) reported that larger and heavier seedlings of sorrel and sweet corn were obtained in soil treated with terramycin solution and that the *in vitro* growth of virus tumor tissue from the root of sorrel *(Rumex acetosa)* was stimulated by this antibiotic at a level of 5 ppm. In the experiments with the corn seedlings the weight differences at the time of sampling were large, and seemingly far outside experimental error. Some additional data on radish and cucumber seedlings were presented in a later paper by the same author (4). He further recognized that terramycin is adsorbed by soil components and that the actual concentration to which the seedling is exposed in soil treatment experiments may be much lower than that applied. Later Nickell and Finley (5) demonstrated stimulation of the growth of duckweed *(Lemna minor)* in sterile culture at levels of 1 to 5 ppm., but inhibition at certain higher concentrations. Pramer (7) studied the uptake of a number of antibiotics, including terramycin, by cucumber seedlings, and while he could find no convincing evidence of terramycin uptake, he reported the stunting of root and shoot growth by concentrations of this antibiotic greater than 50 μg./ml.

Because of the agronomic implications of the reports of terramycin stimulation and extrapolations made from them in the popular press, numerous experiments were initiated in 1953 to investigate any responses induced in plants by terramycin treatment. The majority of these were wholly negative and will therefore only be mentioned briefly.

[1] Paper No. 9 from the Plant Nutrition Laboratory, Michigan Memorial Phoenix Project No. 32, of the University of Michigan, Ann Arbor, Mich. Received Sept. 2, 1955.

[2] University of Michigan, Ann Arbor, Mich. The author is indebted to Michael Hlady and Leo Vander Beek for assistance in these experiments.

RESULTS

Laboratory Studies

Inasmuch as roots are known to be more responsive than shoots to stimulatory or inhibitory substances, several experiments on the effect of terramycin on root elongation and root weight increases were carried out on cucumber, corn, flax, and barley, using essentially the method of Ready and Grant (8). The elongation of the primary roots of cucumber (var. Early Fortune) was extensively inhibited at terramycin concentrations of 5 to 10 ppm. (figure 1). The concentration causing 50% inhibition at 25° C. in 4 days was 9 ppm. Flax (var. Marine) was equally responsive, but corn (Golden Cross hybrid) was less affected at these levels (figure 2). The concentration causing 50% inhibition was approximately 5 times greater. No evidence of stimulation of elongation by low concentrations of terramycin was found in these experiments.

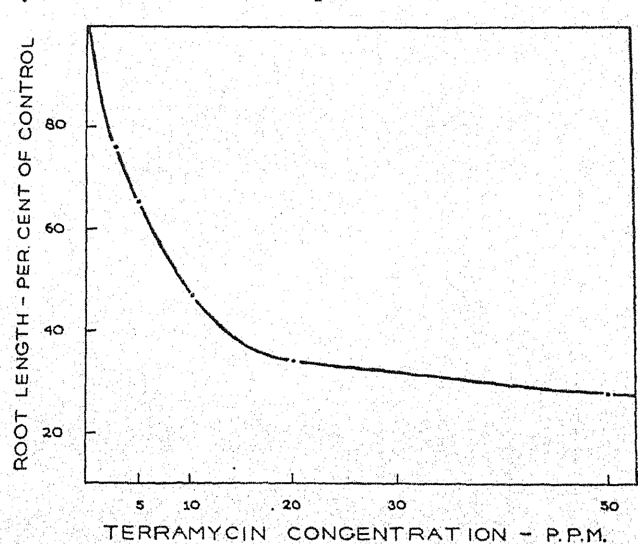

FIG. 1.—Effect of terramycin on the elongation of the primary roots of cucumber seedlings var. Early Fortune at 25° C. for 4 days.

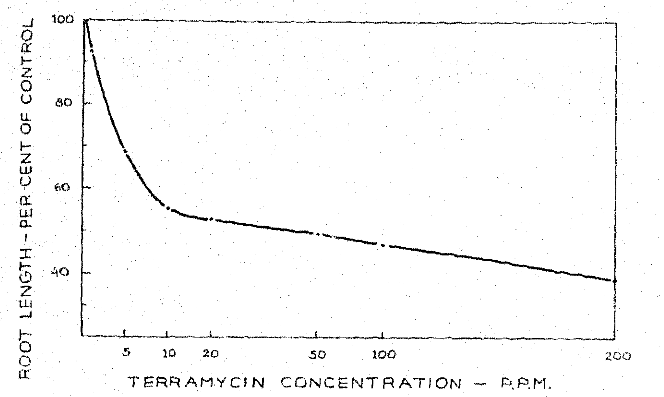

FIG. 2.—Effect of terramycin on the elongation of the primary roots of Golden Bantam hybrid sweet corn at 25° C. for 4 days.

The inhibitory effect of terramycin on root growth was also apparent in studies with barley seedlings (var. Atlas) in which the dry weight of roots obtained in 6 days at 25° C. in the dark, under standard conditions, was determined (6). These experiments involved only effects on the conversion of reserve material from the endosperm to roots. In 2.5 ppm. terramycin solution the root weight was reduced about 40%. Substantially higher concentrations did not bring about greater inhibition and even at 100 ppm. the root weight still exceeded 50% of the control (figure 3). Such a response curve is distinctly unusual and justifies closer examination. However, the significant feature as far as this report is concerned is that no stimulation of rate of weight increase in barley roots was found. High concentrations of terramycin were noted to induce abnormal coleoptile curvature or to impair the normal polarity of the barley shoots, a response perhaps related to that observed by Kribben (2), which will be discusseed elsewhere.

Greenhouse Studies

In the original experiments by Nickell (3) in which apparent stimulation of growth of corn and sorrel seedlings was observed, the seeds were planted in soil in flats watered with a 5 ppm. solution of terramycin. Accordingly, experiments of this type were carried out in divided flats using composted greenhouse soil, of high fertility status, topsoil of relatively low fertility, vermiculite, or sand. Counted numbers of seed of corn (Ohio M-15), oats (Clinton), barley (Moore) or soybean (Hawkeye) were planted uniformly in replicated flats, one half of each of which was watered with 10 ppm. terramycin, and the other half with distilled water initially and as required. Sets of flats were placed in constant temperature rooms held at 20°, 25° and 30° C. until emergence, after which they were placed in a greenhouse without temperature control. The seed lots were all of high percentage germination and vigor, and the experiments were carried out in June and July under good light conditions.

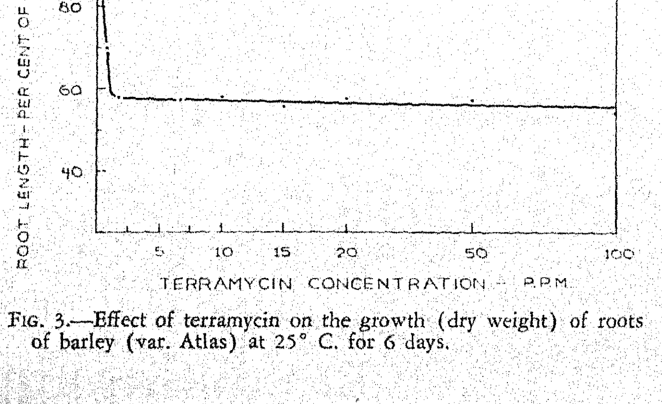

FIG. 3.—Effect of terramycin on the growth (dry weight) of roots of barley (var. Atlas) at 25° C. for 6 days.

Counts of emergence were made at suitable intervals, but no differences in percentage germination or time of emergence, ascribable to the terramycin treatment, were found at any temperature or on any substrate. Measurements of the height of the individual seedlings of each species were continued daily for 14 days after emergence and at no time were significant differences due to treatment found.

The same four species were included again, 1 month later, in a similar experiment limited to soil and vermiculite, and to a pre-emergence temperature of 30° C. Again, no differences in emergence or size of seedlings were observed as a result of the terramycin treatment. These conclusions are based on many thousands of measurements.

Field Studies

Replicated plot experiments on corn (Michigan 480) were carried out at the University of Michigan Botanical Garden in 1953 and 1954, and on soybeans (Hawkeye) also in 1954. In none of these was there a significant increase in yield due to terramycin treatment. The plantings, which were made by hand to ensure complete uniformity, were under close observation, and many counts or measurements of the number and size of plants or plant parts were made.

The experiments were essentially similar and involved the following treatments:

1. seed untreated, planted dry
2. seed soaked in water overnight at 3° C. before planting
3. seed soaked in 10 ppm. terramycin overnight at 3° C. before planting
4. seed untreated, planted dry, watered once with water 1 day after planting
5. seed untreated, planted dry, watered once with 10 ppm. terramycin 1 day after planting.
6. as *(4)* above, but watered 3 times, 1, 8, and 15 days after planting (1953), and on 1, 4, and 10 days after planting (1954).
7. as *(6)* above, but watered 3 times with 10 ppm. terramycin.

Watering was carried out with a sprinkling can in such a way that an area approximately 8 inches each side of each corn hill or soybean row was wetted uniformly (2.5 gallons per 19-hill corn plot, 1 gallon per 10-foot soybean row). In both years, the early season rainfall was such that germination and seedling growth were not delayed. Treatments 2 and 3 involving pre-soaking of seed were not included in the 1954 experiments because of an adverse effect in 1953 on seedling establishment, and number of primary stalks. Certain differences in the rate of growth ascribable to treatment were apparent in the 1953 corn plots, but in 1954 neither the corn nor the soybeans showed any transitory responses. The following tentative conclusions were reached in 1953 on corn:

1. Emergence and early vigor (7 to 10 days after planting) were clearly favorably affected by terramycin watering.

2. Terramycin watering did not significantly affect the survival rate at 14 days, but somewhat increased the number of larger seedlings.

3. Repeated watering with terramycin (3 times) was no more effective than a single treatment with respect to the items listed in *(2)* above.

4. Plots watered once or 3 times with terramycin bore more main stalks at 36 and 69 days and had a higher ear count.

5. Yields of husked corn were not increased by terramycin watering.

In 1954 particular attention was paid to the verification of the observations listed above, but at no time were there seen such differences ascribable to terramycin treatments. Almost 100% stands were obtained, with remarkable uniformity between plots.

DISCUSSION

The experiments reported herein do not provide support for the claim that terramycin stimulates the growth of higher plants. On the contrary, in the absence of soil, root elongation and root growth are unquestionably inhibited by exposure to terramycin at low concentrations. In soil or vermiculite 5 to 10 ppm. terramycin is not inhibitory, whereas in water, root growth is substantially reduced at these levels.

These results confirm and amplify the general findings of Barton and MacNab (1) who, however, did observe somewhat better growth of wheat roots when terramycin was added in certain experiments involving distilled water. It appeared, however, that the terramycin overcame some toxic influence of the distilled water, and that at higher terramycin levels, inhibitory responses occurred.

It remains to account for the apparent stimulation of seedling growth observed by Nickell (3, 4) and for that in our corn plots in 1953. In Nickell's case, the seed corn used was of low percentage germination, but in our experiments seed having almost 100% germination was used. Even so, the probable explanation common to both is that the terramycin solution applied shortly after planting exercised a protective effect on the seedling by suppressing the development of organisms, some of which might otherwise have caused injury to the developing root system. These would be non-specific pathogens of the type associated with damping-off. Nickell (4) observed a higher percent germination of corn and hybrid cucumbers in terramycin-treated flats, and repeated the corn experiment several times with the same results, presumably on the same batch of soil. If protective action rather than stimulation is the explanation of the responses observed, then the presence or absence of certain organisms in the soil population and the environmental conditions at the time of germination would determine whether or not early growth differences might be seen. Unless such protective action resulted in a substantial difference in stand, or the later weather conditions were such that there would be clear advantage from an early vigorous start, it is not to be anticipated that yield differences would ultimately result.

This explanation clearly does not account for the stimulation observed in *Lemna minor* grown aseptically (5) nor the effects on the virus tumor tissue of *Rumex* (3), but neither of these systems can be considered as in any way representative of a normal higher plant. Moreover, the *Lemna* data showed certain peculiarities that suggested that the stimulatory effect might be indirect rather than direct.

SUMMARY

The effects of terramycin (oxytetracycline) on root growth and seedling development of some crop plants were examined critically, but no evidence supporting the claim that terramycin stimulates the growth of higher plants was obtained. Root elongation and growth were repressed by terramycin treatment at low concentrations in water or nutrient solution. In vermiculite, sand, or soil, 10 ppm. terramycin caused no detectable change in seedling development in corn, oats, barley, or soybeans. Field yields of corn and soybeans were not increased by terramycin, but indications of a protective effect were obtained in one season. It is probable that the protective antibiotic action of terramycin against non-specific root pathogens accounted for these observations and for those earlier results in which stimulation of growth was claimed.

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Notes

UNDERGROUND DEVELOPMENT OF ALFALFA CROWNS[1]

WHEN a large number of the crown branches of alfalfa is entirely or partially below the soil surface, the insulating value of the soil gives added protection to these overwintering structures. Early research by Brand and Waldron[2] and Blinn[3] indicated that alfalfa varieties with considerable amounts of the crowns underground were better protected from winter freezing, thawing, and drying out than varieties having upright crowns. Smith[4] has suggested that the overwintering crown branches of any legume tend to escape injury in whole or in part from encasement by otherwise damaging ice sheets when the crown is partially or completely underground. The submerged parts gain protection also from low temperatures that prevail during winter. Lebeau[5] has suggested that some alfalfa varieties with numerous underground crown branches may escape killing from the winter crown rot or snow mold in Western Canada.

Observations were made in the trials reported in this paper on the underground development of the crowns of several alfalfa varieties and strains during 1952 and 1953. All observations were made on plants removed from the field in the fall of their seedling year.

Seedings were made on May 26, 1952, and on May 14, 1953, at Madison, Wis., on Miami silt loam soil in single variety rows spaced 2 feet apart. The rows were hand thinned when the seedlings were 6 to 8 inches high so that the plants were spaced 18 to 24 inches apart. In this manner, competition between plants was reduced and more uniform conditions were provided for crown development. The alfalfa foliage was kept free of damaging insects by the frequent use of insecticides.

During early November 1952, and during late October 1953, all of the top growth above the soil was cut off level with the soil surface with razor blades. The first 20 plants in each row were then removed from the soil. After washing, the spread and depth of the underground portion of the crown of each plant was measured in inches. A ruler was placed across the approximate center of the crown and the spread was measured across the widest portion from tip to tip of the longest rhizomes on each side. The depth of each crown below the soil surface was measured perpendicularly from the point of severance of the stems at the soil level to the point of initiation of the lowest rhizome.

Counts were made also on the number of rhizomes which originated from the old and woody basal portion of the primary stem. As they were counted, the rhizomes were removed with a razor blade. The longer rhizomes on the plants of some varieties had several well developed branches. These branches were separated from each rhizome at their

[1] Published with approval of the Director of the Wisconsin Agr. Exp. Station. Received July 5, 1955.

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[5] Lebeau, J. B. The physiology and nature of disease development in winter crown rot of alfalfa. Ph.D. thesis, University of Wisconsin. 1953.

Table 1.—The average underground crown development per plant for several varieties and strains of alfalfa based on 20 spaced plants of each variety which were removed from the field in the late fall of the first year of growth in 1952 and 1953.

Variety or strain	Ave. number of rhizomes	Ave. width of crown in inches	Ave. depth of crown in inches	Ave. length of rhizomes in inches	Ave. dry weight of rhizomes in grams
	1952				
Alaska *falcata*	56	2.46	.74	18.85	.30
Rhizoma	35	3.63	1.03	28.40	1.08
Vernal	31	3.39	1.03	20.83	.62
Grimm	26	2.46	.89	13.51	.42
Ranger	17	2.28	.98	8.94	.29
Buffalo	16	2.01	1.01	7.60	.24
Arizona Common	10	1.61	.81	4.18	.11
L.S.D. 5% level	9	.60	.12	—	—
C.V.	48%	35%	20%	—	—
	1953				
Alaska *falcata*	93	4.88	.86	81.53	1.46
Rhizoma	57	5.99	.97	56.94	1.72
Vernal	48	5.37	1.12	39.84	1.16
Narragansett	41	4.78	.98	27.08	.93
Grimm	36	3.63	.96	23.46	.70
Ranger	30	3.22	.95	18.39	.52
Buffalo	30	2.63	.93	13.10	.40
Arizona Common	14	1.73	.78	4.24	.15
L.S.D. 5% level	11	1.14	.13	—	—
C.V.	44%	42%	22%	—	—

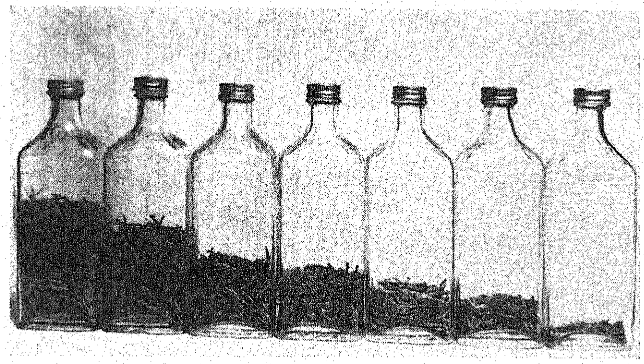


FIG. 1.—The amounts of underground crown branches (rhizomes) on 20 spaced plants of each of 7 varieties and strains of alfalfa as measured in late October of the first year of growth (1953). (L to R) Rhizoma, Vernal, Narragansett, Grimm, Ranger, Buffalo, and Arizona Common.

point of origin. All of the underground pieces removed from the crowns of the 20 plants of each variety were then laid end to end, and the total length was measured in inches. This tissue was oven-dried and weighed. The old and woody portion of the primary stem below the soil surface was not included in any of the counts or weights.

The data presented in table 1 show that the varieties of *Medicago sativa* studied fell in the same order of rank in each year with regard to the amounts of rhizome tissue. Rhizoma alfalfa produced the largest amount of underground crown branches. It was followed by Vernal, Grimm, Ranger, Buffalo, and Arizona Common alfalfa (figure 1), respectively. Narragansett ranked between Vernal and Grimm in the one year that it was studied.

The strain of *M. falcata* examined is used for forage purposes in Alaska. The spread of its crown was not as great as that of some of the varieties of *M. sativa,* and the rhizomes were small in diameter and much branched. However, it produced the largest number of underground crown branches during both years, and the numbers were 38 to 39% greater than for Rhizoma which had the largest number among the *sativa* types studied.

Roots arising from the basal nodes of the older rhizomes were much in evidence in the *falcata* strain. This was noted also, but to a lesser degree, in the Rhizoma, Vernal, and Narragansett varieties. These varieties derive much of their inheritance from *M. falcata,* and this may account, in part, for their greater underground crown development as compared with Grimm, Ranger, Buffalo, and Arizona Common.

Differences among the varieties and strains in the average depth of the crowns below the soil surface were not very apparent. The statistical significance of the data may result from the fact that in each year the crowns of the *falcata* strain and of the Arizona Common were consistently shallower in depth than the crowns of the other varieties in the study.

The data indicate that measurable differences exist in the underground development of the crowns among alfalfa varieties and strains. If a spreading underground crown having a large number of rhizomes is correlated with survival under severe winter conditions, as suggested by this study, it would be of considerable importance in the improvement of alfalfa.—DALE SMITH, *Wisconsin Agr. Exp. Station, Madison, Wis.*

THEORETICAL PROPORTION OF HETEROZYGOSITY IN POPULATIONS WITH VARIOUS PROPORTIONS OF SELF- AND CROSS-FERTILIZATION[1]

ATTEMPTS to utilize hybrid vigor in crops which are difficult to emasculate and cross-fertilize on a commercial scale usually involve advanced generation hybrids or synthetic varieties. The value of such populations will depend at least partially upon the amount of hybrid vigor they retain. Since hybrid vigor is strongly correlated with heterozygosity it would seem profitable to determine the amount of heterozygosity expected in each hybrid generation.

When only random or cross-fertilization occurs, the proportion of heterozygosity immediately becomes stabilized at 2pq where "p" equals the frequency of gene *B* and "q" equals the frequency of gene *b*. When only self-fertilization occurs, heterozygosity is reduced by $\frac{1}{2}$ each generation and approaches zero as a limit. However, when reproduction is partially by self- and partially by cross-fertilization, heterozygosity approaches some limit other than zero depending upon the proportion of self-fertilization.

A simple formula for determining the proportion of heterozygosity for any filial generation derived from any parental population can be developed as follows: In any generation the genotypic ratio will be:

$$p - h/2\ AA : h\ Aa : q - h/2\ aa$$

where h = the proportion of heterozygosity and p and q represent gene frequencies as mentioned above. If we assume no selection and let $r = \frac{1}{2}$ the proportion of self-fertilization and a = the proportion cross-fertilization, then the proportion heterozygosity (H) in the first filial generation could be represented by the terms: $2pqa + hr$; in the second generation by the terms $2pqa + 2pqar + hr^2$; in the third by $2pqa + 2pqar + 2pqar^2 + hr^3$; and in the nth by $2pq(a + ar \ldots + ar^n - 1) + ar^{n-1}$. Using the standard algebraic formula for summing a geometric progression[3] results in a general formula:

$$H = 2pq\left[\frac{a(1-r^n)}{1-r}\right] + hr^n.$$

This formula is quite useful for several reasons. It can be used for any parental population whether it is in equilibrium or not. It can be used for any gene frequency. And it can be used for any ratio of selfing and crossing. Where selfing is 100% the formula reduces to $H = hr^n$ and where crossing is 100% it becomes: $H = 2pq$. The theoretical limit which heterozygosity approaches may be obtained quite easily. As "n" in the general formula increases without limit, r^n approaches zero, reducing the formula to:

$$\lim_{n \to \infty} H = 2pq\left(\frac{a}{1-r}\right).$$

[1] Contribution from the Genetics Department, Texas Agr. Exp. Sta., College Station, Tex. Received July 18, 1955.

[2] Graduate Student on leave from West Pakistan and Associate Professor of genetics respectively.

[3] The basic progression was first suggested by Prof. C. B. Godbey to the junior author in 1946.

The proportion of each homozygous genotype can be determined for any generation if "H" and "p" and "q" are known. *AA* will equal $p - \frac{H}{2}$ and *aa* will equal $q - \frac{H}{2}$.

In some populations such as mixtures of homozygous lines used as the beginnings of synthetic varieties, there is no heterozygosity. Thus "h" equals zero and the general formula reduces to:

$$H = 2pq\left[\frac{a(1-r^n)}{1-r}\right].$$

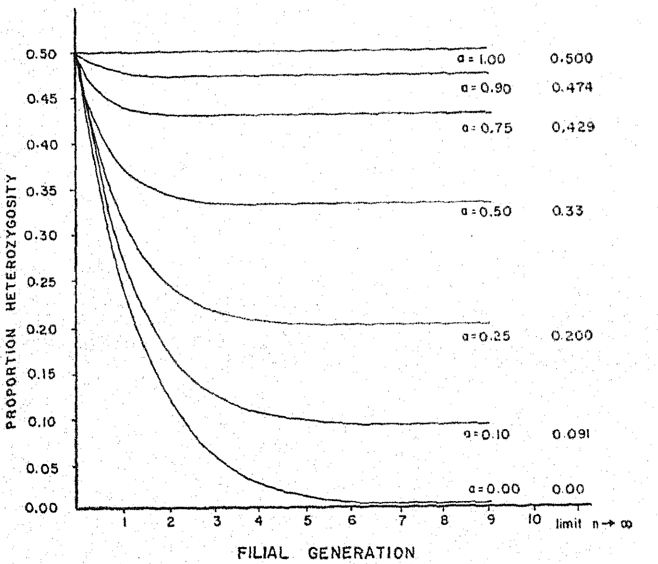


FIG. 1.—Proportion heterozygosity with different proportions of cross-fertilization where $p = q = \frac{1}{2}$ and $h = 1$.

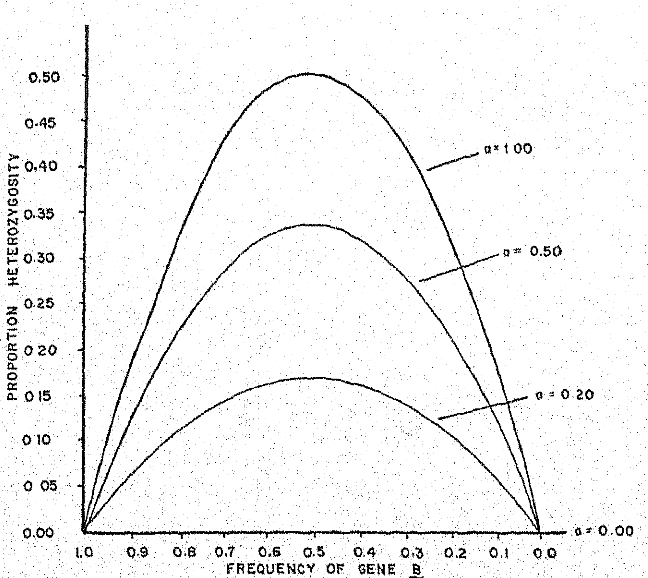


FIG. 2.—Limit of heterozygosity with different gene frequencies and proportions of cross-fertilization.

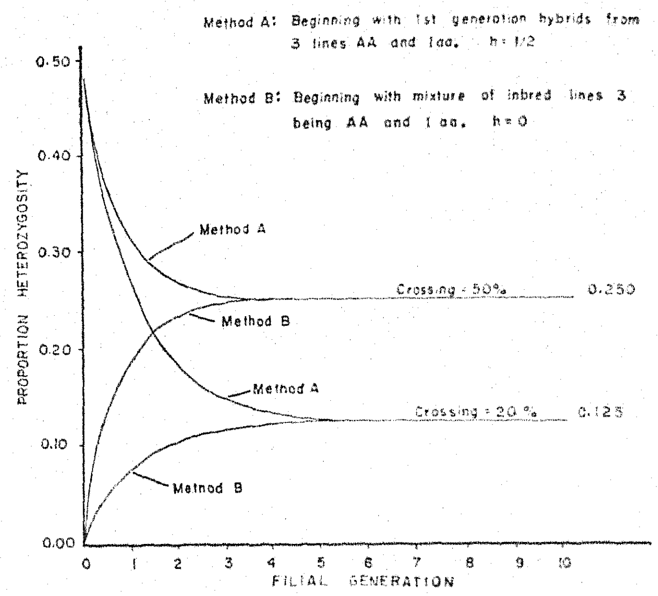


FIG. 3.—Proportion heterozygosity in synthetic varieties made up by two different methods where $p = \frac{3}{4}$ and $q = \frac{1}{4}$.

Where one hybrid plant is the source of later generations, $p = q = \frac{1}{2}$ and $h = 1$. The formula then becomes:

$$H = \left[\frac{\frac{a}{2}(1-r^n)}{1-r}\right] + r^n.$$

This is probably the most common situation to be expected when calculating heterozygosity in advanced generation hybrids in highly self-fertilized crops.

Figure 1 illustrates the effect of the percentage of cross-fertilization on the proportion of heterozygosity in the first 10 filial generations and at the theoretical limit of heterozygosity with 7 different percentages of cross-fertilization. Figure 2 illustrates the effect of gene frequency on the theoretical limit of heterozygosity with 4 different percentages of cross-fertilization. In any case other than 100% selfing a situation of $p = q = \frac{1}{2}$ gives the maximum limit of heterozygosity. Figure 3 shows how the proportion of heterozygosity approaches its theoretical limit under two methods of producing synthetic varieties. As indicated by the two sets of curves, synthetics made from controlled crosses or first generation hybrids have a greater percentage of heterozygosity than those made from mixtures of inbred lines. However, two or more generations usually would be required before an adequate seed supply would be available for commercial purposes. At this time the advantage gained by starting with hybrids instead of inbred lines would be small and perhaps not worth the cost of making the hybrids.

Other formulae for determining the proportion of heterozygosity at any generation have been developed by Garber.[4] They are quite accurate, but in the opinion of the authors are more complex and unwieldly than the ones presented here.—MAHBUB ALI, *Graduate Student on leave from West Pakistan, and* HENRY H. HADLEY, *Associate Professor of Genetics, Texas A&M College.*

[4] Garber, M. J. Approach to genotypic equilibrium with varying percentages of self-fertilization and cross-fertilization (one autosomal gene-pair). Jour. Hered. XLII, No. 6:299–300. 1951.

DETERMINING DISEASE LOSSES IN OATS[1]

RELIABLE information on losses from diseases is needed for the more effective planning of breeding programs. Most yield loss estimates are made from observations or from comparisons, as between resistant and susceptible varieties. More accurate estimates are obtained in properly designed tests under artificially produced epiphytotics with adequate controls. Isogenic lines logically measure disease losses most accurately since they minimize the effect of variables other than disease reaction. This paper presents data on the determinations of losses in oats from the Victoria blight organism, *Helminthosporium victoriae* M. and M. The material is of particular interest since the parent stock was believed for many years to be a genetically pure line of oats. The lines used in this study became identifiable only in the presence of the pathogen which first appeared in the eleventh generation of selfing of the parent F_4 line. Thus the lines reported are essentially isogenic although not selected as such in the usual way.

Selection 526, the oats used in this study, was derived from the cross Ithacan × Victoria made in 1936 by Love and Craig. The F_4 line was an extremely uniform high-yielding strain characterized by unusually short straw which emphasized its uniform appearance (the variety Craig was selected from this line). However, in 1947–48 when Victoria blight reached epiphytotic proportions in New York State, this line, which had been selfed for 11 continuous generations and was considered to be homozygous, was found to consist of plants resistant, susceptible, and heterozygous for reaction to blight. Lines in each of these classes were selected and increased under disease-free conditions at Yuma, Ariz., during the winter of 1950. In the late spring of 1951, the 12 lines (3 resistant, 6 segregating, 3 susceptible) were planted in a split-plot arrangement replicated 8 times in each of 4 locations at Ithaca, N. Y. Resistant Mohawk and susceptible Vicland were used as check varieties. Entries were planted in single rod-row plots 1 foot apart, the central 15 feet being harvested for yield purposes. The main split was between inoculated and uninoculateed plots, which were separated by two rows of Mohawk to minimize the danger of spread of the pathogen. The oats were inoculated by dipping the seed in a spore suspension of *H. victoriae* before planting. Separate planters for inoculated and uninoculated seed were used and necessary precautions taken to prevent the spread of the inoculum from the inoculated to the uninoculated plot while planting. The results from these tests are summarized in table 1.

The very similar yields of the 12 strains when not subjected to the influence of Victoria blight give evidence of the isogenic nature of these lines. In the inoculated plots, however, the effect of blight on the segregating and susceptible strains was marked and clearly evident. The reduction in yields was 65 and 96%, respectively, when compared with the same disease group in the uninoculated plots. This reduction was due chiefly to the poor stand caused by the seedling killing of crown rot. The few susceptible plants which did mature lodged badly and produced light gain of poor quality. Under the same conditions the resistant strains actually showed an increase of 23%, this being due to the removal of adjacent row competition which could have been avoided through the use of multiple-row plots.—J. P. CRAIGMILES, *and* N. F. JENSEN, *Associate Agronomist, Georgia Agr. Exp. Sta., Experiment, Ga., and Professor of Plant Breeding, Cornell University, Ithaca, N. Y., respectively.*

Table 1.—The mean yield of oats in each of the groups resistant, segregating, and susceptible showing the difference in yield between groups as well as between inoculated and uninoculated.

Disease group mean	Yield in bu. per acre		Reduction or gain in yield
	Uninoc.	Inoc.	
3 resistant strains	31.4	38.5	+ 7.1
6 segregating strains	33.3	11.8	−21.5
3 susceptible strains	31.3	1.3	−30.0
Mean of all disease groups	32.0	17.2	−14.8

[1] Part of a thesis submitted to the faculty of the Graduate School of Cornell University in partial fulfillment of requirement for the Ph.D. degree by the senior author. Jour. Series No. 288, Georgia Agr. Exp. Sta., Experiment, Ga., and Paper No. 321, Department of Plant Breeding, Cornell University, Ithaca, N. Y. Received July 28, 1955.

THE OCCURRENCE OF TRISOMICS AND OTHER ANEUPLOIDS IN A CROSS OF TRIPLOID × DIPLOID *Sorghum vulgare*[1, 2]

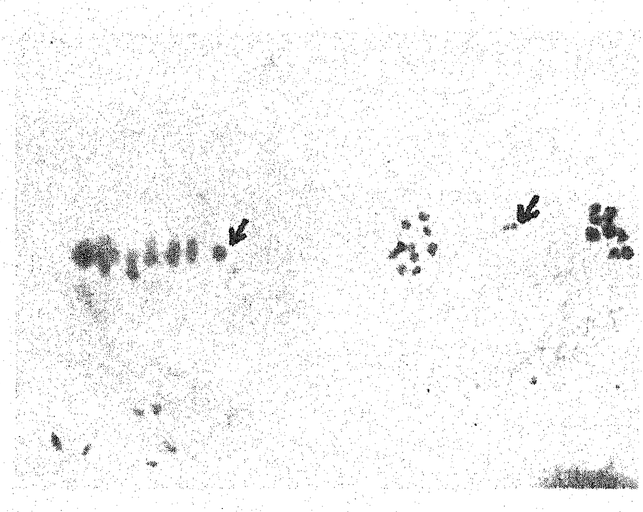
AN OFF-TYPE plant found in 1953 in a row of White Collier sorgo at the Fort Hays (Kans.) station was early, had a spindly stalk, tillered and side-branched profusely, and was highly sterile. Externally it closely resembled a sorghum haploid as described by Brown.[3] The aberrant plant, upon removal to the greenhouse, was completely sterile under bagging, and a cytological check revealed it to be a triploid rather than a haploid. The triploid is apparently of hybrid origin because many plant characters do not resemble White Collier.

In the field, more than 100 poor-quality seeds had been set on the triploid by open pollination of a large number of florets. In the spring of 1954, 50 of these seeds planted in bands produced 27 viable plants, which were transplanted to the field. Two of these were destroyed by rabbits. Sporocytes were collected from the remaining 25 triploid-diploid progeny and analyzed with the following results: 9 normals, 2N; 9 trisomics, 2N+1; 3 double trisomics, 2N+1+1; 1 tetrasomic, 2N+2; 1 triple trisomic, 2N+1+1+1; 1 trisomic-tetrasomic complex having the karyotype 2N+2+1+1+1+1; and 1 unidentified aberrant.

[1] Joint contribution from the Field Crops Research Branch, A.R.S., U.S.D.A., and the Fort Hays Branch, Kansas Agr. Exp. Sta.; Contribution No. 93 from the Fort Hays Branch Exp. Sta. Received Aug. 27, 1955.

[2] These results are a portion of the material submitted by the senior author in partial fulfillment of the requirements for the M.S. degree at Kansas State College.

[3] Brown, Meta Suche. Haploid plants in sorghum. Jour. Hered: 34:163–166. 1943.



A B

FIG. 1.—Meiotic figures of trisomic *Sorghum vulgare;* A, metaphase I with normal orientation of extra univalent on equatorial plate; B, lagging and dividing univalent at anaphase I. (Ten bivalents not all discernible because of clumping.)

All of the 16 aneuploids showed high sterility under bagging but generally set abundant seed when pollinated by normal plants. Figure 1 shows the extra univalent of a trisomic plant at metaphase I and a rather typical subsequent lagging behavior at anaphase I. An occasional univalent proceeded to one pole and divided during the second meiotic division rather than the first.

The lethality of the small population of sorghum triploid × diploid progenies was 46%, about the same as found by McClintock[4] in maize trisomics. In the surviving population McClintock found 45% aberrant plants, including 16% trisomics. In this sorghum population, 64% of the plants were aberrants, which included 36% trisomics. Adequate populations might reveal more similar percentages for the two crop species.

The value of trisomics is apparent in a species such as *Sorghum vulgare,* in which only four plural linkage groups have been studied. Trisomic plants can be propagated vegetatively and used immediately in test crosses to determine the nulliplex, simplex, duplex, or triplex nature of a single locus, or trisomic stocks can be produced in given lines by repeated backcrossing.

Elimination of normal plants from a triploid-diploid cross on the basis of fertility would concentrate the aberrants and increase the chance of isolating trisomics. This would facilitate cytological investigations of sorghum which are difficult otherwise. Frequencies of only a few trisomics per hundred plants should provide for the recovery of all ten testers with little difficulty.—MARY EMMA PRICE, *Assistant, Kansas Agr. Exp. Sta.; and* W. M. ROSS, *Associate Agronomist, Field Crops Research Branch, A.R.S., U.S.D.A., located at the Fort Hays Branch Station.*

[4] McClintock, Barbara. A cytological study of triploid maize. Genetics 14:180–222. 1929.

Fellows Elect, 1955

KLING L. ANDERSON

KLING L. ANDERSON was born at Axtell, Nebr., in 1910. He received his B.S. degree in 1936 from the University of California and his M.S. degree from Kansas State College in 1938. His Ph.D. degree was obtained from the University of Nebraska in 1951.

Mr. Anderson was a research assistant at Kansas State College in 1936–37 and became assistant professor in pasture improvement in 1938. He was advanced to associate professor in 1942 and to professor in 1946. He has devoted his life to teaching and research in the fields of pasture and range improvement and management. He has been especially active in developing improved varieties and strains of native and introduced grasses for eastern Kansas. He is one of the leading research workers in the development of improved strains of Sudangrass that have heavy leaf development and low toxicity. His studies on the influence of nitrogenous fertilizers on the yield and composition of bromegrass and on seed production of bromegrass have given outstanding results as have his studies on the use of legumes in pasture mixtures.

In 1952 Mr. Anderson was granted a Fulbright Scholarship for study and travel in New Zealand where he spent 9 months.

Mr. Anderson has published a great many technical and popular articles on pasture management and improvement.

Anderson Beard Browning

DAVID F. BEARD

DAVID F. BEARD was born in Wood County, Ohio, in 1912. He received the B.S. degree in agronomy from the Ohio State University in 1935 and the Ph.D. degree from the same institution in 1940. He was appointed extension agronomist at Ohio State University in 1939 and served in that capacity until 1950. During this same period, beginning in 1940, Dr. Beard was secretary-treasurer of the Ohio Seed Producers Association. In 1950 he moved to Beltsville, Md., as assistant head, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering. In 1951 he was named head of that division, the position he now holds.

Dr. Beard's principal work has been in seed improvement and seed certification and he is a recognized leader in the country in that field. In 1946 he held a special appointment in the U. S. Department of Agriculture to make a survey of the problems of production, movement by the trade, and marketing of certified seed, especially of the grasses and legumes. On the basis of his studies, he made recommendations of important changes in the seed improvement and seed certification program that led to the adoption by the International Crop Improvement Association of the principles of inter-state certification.

He has served, since the beginning of the National Foundation Seed Project, as chairman of the Planning Committee for that Project. To him goes much of the credit for development of sound principles and procedures in operation of the Foundation Seed Project.

Since assuming his responsibilities as head of the now Forage and Range Section, Agricultural Research Service, Dr. Beard has demonstrated repeatedly his leadership in forage crop research in the United States.

GEORGE M. BROWNING

GEORGE M. BROWNING was born at Verona, Mo., in 1908. He received the B.S. degree from the University of Missouri in 1932, the M.S. and Ph.D. degrees from the University of West Virginia in 1934 and 1938. He was a soil conservationist with the Soil Conservation Service after 1935 and appointed senior soil conservationist in Iowa in 1943. In 1947 he was appointed assistant director of the Iowa Agricultural Experiment Station in charge of the experimental farms program and in 1951 was promoted to associate director, the position he now holds.

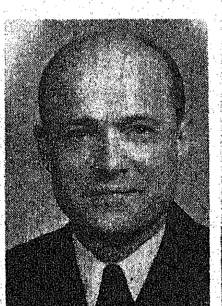
Dr. Browning has made many reports to the Society and elsewhere on soil physics and soil chemistry, and in his major field of research, soil conservation.

RALPH M. CALDWELL

RALPH M. CALDWELL was born at Brookings, S. Dak., in 1903. He received the B.S. degree from South Dakota State College in 1925; and from the University of Wisconsin he received the M.S. degree in 1927 and the Ph.D. in 1929. His training was particularly in plant pathology and plant breeding. In 1930, after 2 years as Wisconsin's state leader in the barberry eradication program, he joined the staff of the botany and plant pathology department at Purdue University in charge of small grain disease control. He was appointed head of that department in 1937, and resigned as head in 1954 to devote full time to research in small grain improvement.

Varieties released to date from projects under Dr. Caldwell's leadership are Benton, Clintland, Bentland, and Newton oats, and Vigo, Knox, Vermillion, and Dual soft red winter wheats. Dr. Caldwell has made notable contributions to our knowledge of the leaf rust disease of wheat, particularly the factors of loss due to leaf rust attacks and the distribution of physiologic races of the pathogen. In addition to administering the department and providing leadership in the development of broad research programs within the department in microbiology, genetics, physiology, and plant pathology, Dr. Caldwell organized one of the most progressive small grain improvement projects in the nation. Through judicious selection and combination of germ plasm from many distantly related sources, he has developed wheat varieties with yield advantages unprecedented in the crop. He discovered two of the important sources of resistance to the Eastern strain of Hessian fly, and the Dual variety incorporates the resistance of one of these.

He has been a member of the Society for over 20 years and has been on numerous committees and programs.


Caldwell


Chapman


Colwell

HOMER D. CHAPMAN

HOMER D. CHAPMAN was born at Darlington, Wis., in 1898. He received the degrees B.S., M.S., and Ph.D. from the University of Wisconsin in 1923, 1925, and 1927 respectively, his major subject being soil chemistry. He was made assistant chemist in the Citrus Experiment Station of the University of California at Riverside in 1927; associate chemist and chairman of the division of agricultural chemistry in 1938; professor of soils and plant nutrition and chairman of that division, 1944 to 1955. He was president of the Western Society of Soil Science in 1938–39, and chairman of the division of soil chemistry in the Soil Science Society of America, 1941–42.

He has been invited to give papers at several international congresses, and has published nearly 100 research papers, mostly relating to soil chemistry in relation to growing of citrus.

WILLIAM E. COLWELL

WILLIAM E. COLWELL was born at Tarkio, Mo., in 1915. He received the B.S. degree from the University of Nebraska in 1936, the M.S. degree from the University of Idaho in 1938, and Ph.D. in soils from Cornell University in 1942. He was associate professor of agronomy at North Carolina State College from 1942 to 1944, when he went with the Rockefeller Foundation in Mexico for two years. He returned to North Carolina State College of Agriculture in 1946, becoming head of the department of agronomy in 1948. In 1953 he was appointed assistant director of the North Carolina Agricultural Experiment Station, a position which he holds at present.

Dr. Colwell has published many articles in *Agronomy Journal* and *SSSA Proceedings*. He has been chairman of the Plant Nutrients Division, chairman of the Committee on Fertilizers, and secretary of the Southern Branch of the Society. He has been particularly active in the study of the mineral nutrition of peanuts, but has also published on a wide range of topics, and now as assistant director of the North Carolina station, he is in charge of tobacco research.

JOHN P. CONRAD

JOHN P. CONRAD was born in Rialto, Calif., in 1893. He received his B.S. degree at the University of California in 1917, and his Ph.D. degree at the same institution in 1933. He joined the staff of the department of agronomy in 1921, and is now professor of agronomy and agronomist at the experiment station.

Dr. Conrad has devoted most of his efforts toward investigation on the relation of soil organic matter to soil fertility, and the relation of organic transformation to the availability of nutrient ions. He has also given considerable attention to the availability of various forms of nitrogen phosphorus and sulphur in California soils. His studies on the hydrolysis of organic nitrogen by thermolabile catalytic activity are outstanding. He has about 50 papers and publications to his credit.

Dr. Conrad has been an effective teacher. In 1948 he was selected by his colleagues to deliver the annual faculty research lecture, his subject being "Crop Residues on Humus in Relation to the Supply of Plant Nutrients". He has served on the Advisory Board of Institute of Geophysics, and as representative of the 11 western states on the Fertilizer Work Group.

He was elected vice-president of the Western Society of Soil Science in 1950–51 and president in 1951–52.

GEORGE H. DUNGAN

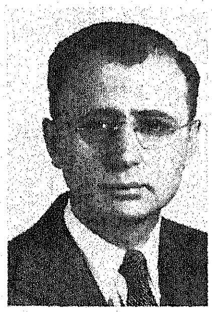
GEORGE H. DUNGAN was born at Rocklane, Ind., in 1887. He was awarded the B.S. degree in 1917 and M.S. degree in 1921 by the University of Illinois, and the Ph.D. degree in 1925 by the University of Wisconsin.

He began his professional career as assistant in agronomy, University of Illinois, in 1917, and advanced to professor of crop production in 1936, a position and rank he has held to the present time.

On July 1, 1953, he was assigned to Allahabad Agricultural Institute, Allahabad, India. In this assignment he was made chair-


Conrad


Dungan


Frolik

man of the research project committee, and leader of the Illinois Program, has taught courses in plant breeding and crop production, and carried on researches including corn breeding, hybrid corn performance tests, and methods of growing corn.

Dr. Dungan's major field of activity at University of Illinois is field crop production as influenced by growth conditions, i.e., experimental crop ecology. Specific problems to which he has given attention are: hail injury, effect of detasseling corn, function of suckers on corn, delayed planting of corn for corn borer control, rate of planting small grains, and effect of varying the space between corn plants on yield and quality.

He is rated as an outstanding teacher, served on the student activity committee of the Agronomy Society for several years, has been a grain judge at many county and student contests, and has been much in demand as a speaker at father-son banquets.

He is the author of over a dozen papers in *Agronomy Journal,* and author or co-author of over sixty bulletins and circulars of the Illinois Experiment Station and Extension Service.

ELVIN F. FROLIK

ELVIN F. FROLIK, professor and former chairman of the department of agronomy and now associate director of the Nebraska Agricultural Experiment Station, was born at DeWitt, Nebr. in 1909. Dr. Frolik received his B.S. degree from Nebraska in 1930, the M.S. degree in 1932 and the Ph.D. from Minnesota in 1948. He was a graduate assistant in agronomy from 1930 until 1933; served as county agent for a year; was farm adviser for a life insurance company during 1934 and 1935; and extension agronomist, University of Nebraska 1936–1945. Since 1945, Dr. Frolik has been a staff member of the department of Agronomy. He spent two summers as a research fellow at the California Institute of Technology. Dr. Frolik served as one of the representatives of the University of Nebraska in developing an exchange program with Turkey. He initiated work on atomic irradiation of crops in 1947 and is author of numerous scientific publications and articles.

JOHN E. GIESEKING

JOHN ELDON GIESEKING was born at Altamont, Ill., in 1905. He received a B.S. degree in soils at the University of Illinois in 1927, an M.S. in chemistry, and a Ph.D. in soils from the same institution in 1927 and 1934, respectively. During the academic year 1929–30, he studied with Kappen at the University of Bonn, Germany, and in 1933–34 he held a National Research Council grant, working with Dr. Hans Jenny at the University of Missouri. He returned to the University of Illinois in 1934, where he rose steadily to his present position of professor of soil physics in the department of agronomy.

Dr. Gieseking's research has been in the field of physical chemistry and mineralogy of soils. He has published more than 16 articles and directed many M.S. and Ph.D. theses dealing with ionic-exchange phenomena of clay minerals and soil colloids. His work on the nature and energy of binding of organic ions by soil colloids provided the fundamental basis for much of our present knowledge of aggregate stability and the action of organic matter and soil conditioners. He served as consulting chemist for the Filtrol Corp. in the development of petroleum cracking catalysts.

Prof. Gieseking has been active in the work of the Soil Science Society of America and has served as chairman of Division II—Soil Chemistry, and as recording secretary and historian. He attended the International Society of Soil Science Congresses in Oxford, Amsterdam, and Leopoldville.

ATLEE L. HAFENRICHTER

ATLEE L. HAFENRICHTER was born at Plainfield, Ill., in 1897. He received the B.A. degree from Northwestern College in 1922 and the Ph.D. degree from the University of Illinois in 1926. He went to Washington State College in 1929 as assistant professor of agronomy (forage crops) where he stayed until 1933. He then joined the Soil Erosion Service, now the Soil Conservation Service, U. S. Department of Agriculture. He has been continually advanced in this organization and is now Plant Materials Technician (West).

As chief of the Regional Nursery Division, Soil Conservation Service, U.S.D.A., he directed the work of five Soil Conservation Service nurseries and several other outlying nurseries in the Pacific States in the assembly, testing, selecting, and developing of grasses, legumes, and browse and in determining the cultural and management practices required for their use under a wide variety of conditions. Many new plants were released through crop improvement associations and are in production and use in the Western states. Several new techniques for establishment and management were developed. New plants were made available to other agencies for trial and study.

Dr. Hafenrichter is a frequent contributor to *Agronomy Journal.* He received a Superior Service Award from the U.S.D.A. in 1947.

PAUL H. HARVEY

PAUL H. HARVEY was born in 1911 at St. Paul, Nebr. He majored in agronomy at the University of Nebraska and was graduated in 1934. He then went to Iowa State College and received the Ph.D. degree in June 1938 with a major in genetics. From there he went to North Carolina State College as assistant agronomist, with responsibility for developing new corn and peanut varieties. In 1940, Dr. Harvey was promoted to associate agronomist and placed in charge of corn breeding. The project was made cooperative with the U.S.D.A. in 1942.

In 1951 he was promoted to professor of agronomy and placed in charge of plant breeding research. In addition to this, all field crop research was placed under his jurisdiction in 1954. Along with research and administration, Dr. Harvey has taken an active interest in training graduate students.

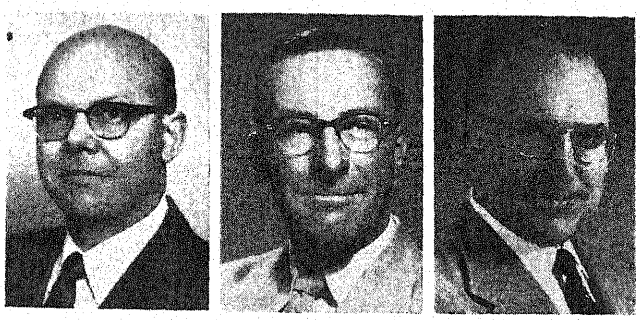
Dr. Harvey's research program has developed many of the corn hybrids that are now used by North Carolina farmers. He found it possible to develop hybrids quickly by crossing good inbreds and single crosses from the Corn Belt states with local southern varieties. These top-cross hybrids produced about 15% higher yields than the common corn varieties used in North Carolina. Later he developed inbred lines and produced double cross hybrids that gave high yields and superior quality, and were insect and disease tolerant.

Dr. Harvey has presented papers at many of the annual meetings of the American Society of Agronomy. He is now a director, and served as program chairman, Division VII, in 1954. He has contributed several articles to *Agronomy Journal,* and published many other agronomic papers.


Gieseking


Hafenrichter


Harvey



Jackson Keller Knoblauch

MARION L. JACKSON

MARION L. JACKSON was born at Reynolds, Nebr. in 1914. He received the B.S. degree with high distinction at the University of Nebraska in 1936, and the M.S. degree in 1937. At the University of Wisconsin he received the Ph.D. degree in 1939.

Except for a brief period at Purdue University in 1946, he has since been continuously in the department of soils, University of Wisconsin, becoming professor of soils in 1950.

Dr. Jackson has published over 30 papers in the *Soil Science Society of American Proceedings* and *Agronomy Journal*, as well as many other papers elsewhere. He has been a member of the editorial board of the *SSSA Proceedings* since 1951, and has served as chairman of many Society committees. He has been active in the study of mineral colloids of soil, soil acidity, and other chemical and physical properties of the soil. He has made extensive use of the electron microscope in the study of soil properties and reactions. Dr. Jackson has been active also in "practical" studies on the use of anhydrous ammonia and in the use of large amounts of fertilizer to boost corn yields.

WESLEY KELLER

WESLEY KELLER was born at Logan, Utah, in 1905. He received his B.S. and M.S. degrees from Utah State Agricultural College in 1929 and 1932, and the Ph.D. degree in plant genetics from the University of Wisconsin in 1939.

He first worked in the Division of Sugar Plant Investigations with sugar beets. In 1939 he joined the Division of Forage Crop Diseases, Bureau of Plant Industry, U.S.D.A., with headquarters at Logan. He has been in that employment with various changes of title since, and is now geneticist, Forage Crop Section, Agricultural Research Service, U.S.D.A. In that time he has been primarily concerned with the breeding of grasses for western range and pasture lands. He has made important contributions to breeding methodology and has produced important improved strains of crested wheatgrass and orchardgrass.

Dr. Keller has also conducted extensive research on irrigated pastures. His trials on scores of pasture mixtures and his cooperative work with various specialists in evaluating yield and palatability of these species has resulted in the introduction of higher production and more palatable pasture mixtures for the inter-mountain area.

He has been a loyal supporter of the American Society of Agronomy since 1930, has contributed extensively at meetings and to *Agronomy Journal*, and was active in establishing the Western Society of Crop Science.

HAROLD C. KNOBLAUCH

HAROLD C. KNOBLAUCH was born near Blissfield, Mich., in 1908. He obtained his B.S. degree from Michigan State College in 1931, the M.S. degree in soil science from the University of Rhode Island in 1953 and the Ph.D. degree in agronomy from Rutgers University in 1942. From 1931–35 he served as assistant agronomist at the Rhode Island Agricultural Experiment Station. He joined the Soil Conservation Service in 1935, and from 1938–40 he was in charge of research for the Soil Conservation Service in the State of New Jersey, with headquarters at New Brunswick. In November of 1940 he joined the staff of the Office of Experiment Stations, U. S. Department of Agriculture, and became assistant chief of the office, in charge of grant fund administration in 1948. He continued in this work, with a change of title in 1953 to director, State Experiment Stations Division.

Dr. Knoblauch served as chairman of the Soil Science Society of America division of soil technology in 1942, and has published numerous articles in *Soil Science Society of America Proceedings* and *Agronomy Journal*. He was an official member of the U. S. Delegation to the Fourth International Congress of Soil Science held at The Hague, Netherlands, in 1950, was a member of the organizing and executive committee for the Sixth International Grassland Congress held at Pennsylvania State University in 1952.

HERBERT H. KRAMER

HERBERT H. KRAMER, professor of agronomy at Purdue University, was born at Brighton, Colo., in 1916. He received the B.S. degree from Colorado A. & M. College in 1939 and the M.S. degree from the University of Minnesota in 1941.

Between 1941 and 1945 he continued graduate study and also conducted plant breeding research as associate geneticist on the special Guayule Research Project in Arizona and California. Following this assignment he returned to the University of Minnesota and received the Ph.D. degree in 1946. Dr. Kramer has been on the Purdue staff since 1946 and was promoted to the rank of full professor in 1951.

At Purdue he has been a leader in developing a program to survey new crops for potential industrial use in the Mid-west. Since establishing and organizing a plant breeding program in forage crops, Dr. Kramer's efforts have turned to his original interest in fundamental genetics and cytogenetics. He has published over 20 scientific articles dealing with plant breeding and genetics. This work concerned the linkage groups in barley and corn. Dr. Kramer developed unique statistical procedures for these studies, of wide general application.

He was granted a sabbatical leave from Purdue University in the academic year of 1953–54 when he accepted a fellowship at the California Institute of Technology to work on genetic problems in cooperation with Drs. D. G. Anderson and A. E. Longley.

In recognition of his many contributions to plant breeding and genetics, Dr. Kramer received the Stevenson Award for Crop Science in 1953.

Dr. Kramer has been chairman of Division VII, has been member and chairman of the vital budget and finance committee of the Society, has published extensively in *Agronomy Journal*, and is a member of its editorial board.

WILLIAM S. LIGON

WILLIAM S. LIGON was born at Corydon, Ky., in 1903. He was graduated from the University of Kentucky in 1925. He taught in Ohio from 1926 to 1929, then went to the University of West Virginia where he received the M.S. degree in 1930. He completed his Ph.D. in soils at Michigan State College in 1934 and then joined the U. S. Department of Agriculture. He was first assigned to the State of Georgia for one year, to Kentucky for one year, and to Ohio from 1937 to 1943. He then returned to Kentucky, as a joint employee of the University and U.S.D.A. In 1947 he was given a leave of absence to head the soils and fertilizer work in Japan under the Supreme Command of the Allied Powers, with headquarters in Tokyo. Soon

Kramer Ligon Merkle

after his return from this assignment, in 1947, he moved to Knoxville, Ky., to work with the Regional Soil Correlation staff. He is now principal soil correlator, Southern States, Soil Survey, S.C.S., U.S.D.A., in charge of the soil correlation work in the southern region.

He is a long-time member of the American Society of Agronomy and Soil Science Society of America, and was chairman of Division V in 1952.

FREDERICK G. MERKLE

FREDERICK G. MERKLE was born at Detroit, Mich., in 1892. He received the B.S. and M.S. degrees from Massachusetts State College in 1914 and 1917, and the Ph.D. in soils from Cornell University in 1933. He was on the staff of Massachusetts College of Agriculture from 1915 to 1920, and on the staff of Pennsylvania State University from that time on, receiving the title of professor of soil technology in 1932.

His main fields of activity have been soil chemistry, fertilizers and their use, base exchange, soil management, and soil conservation. He has taught graduate and undergraduate courses in soils at Pennsylvania State University for 30 years. Dr. Merkle has published many papers in *Agronomy Journal* and the *Soil Science Society of America Proceedings*. He was chairman of Division IV—Soil Fertility, Fertilizers and Plant Nutrition—in 1952, and has served on many Society committees. He was president of the Northeastern Branch of the Society in 1946.

GERALD O. MOTT

GERALD O. MOTT, professor of agronomy at Purdue University, was born at Hastings, Nebr., in 1912.

He received the B.S. degree from the University of Nebraska in 1934, and from 1934 to 1936 he served as a junior agronomist with the Soil Conservation Service in Texas and Oklahoma. In 1936 he enrolled in the graduate school at Cornell University, obtaining the Ph.D. degree in 1940.

Since joining the Purdue agronomy staff in 1940, Dr. Mott has been a leader in pasture teaching and research. He is recognized as one of the outstanding pasture research men in the United States. He is now leader of a regional project on methods of evaluating pastures.

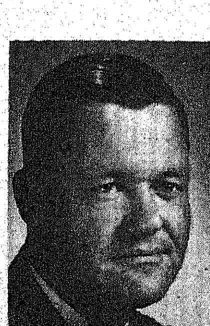
He is president of the Crop Science Society of America and has presented numerous papers at American Society of Agronomy meetings. He has been chairman of the Crop Production and Management and the Turfgrass divisions of the Society.

ROYSE P. MURPHY

ROYSE P. MURPHY was born in Norton, Kans., in 1914. He received his B.S. degree from Kansas State College in 1936, the M.S. degree in 1938, and the Ph.D. in 1941 from the University of Minnesota. He was assistant professor of plant genetics at the University of Minnesota for a year after receiving his degree, then went to Montana State College for 4 years as associate professor of agronomy. Much of that time he was on leave, first on the Guayule Rubber Research Project, then as Ensign and Lieutenant, U.S.N.R.

In 1946 he went to the department of plant breeding at Cornell University, was advanced to professor in 1948, and became head of the department in 1953.

Mott



Murphy

Musser

Dr. Murphy's major field is the breeding of forage crops, particularly alfalfa, timothy, orchardgrass, and smooth bromegrass, although his first work was with corn. He has been active in the affairs of the Society, serving on several committees, and was chairman of the Division of Breeding, Genetics, and Cytology in 1951.

HOWARD B. MUSSER

HOWARD B. MUSSER was born at Williamsport, Pa., in 1893. He received the A.B. degree from Bucknell University in 1914 and the B.S. degree in agronomy from Pennsylvania State University in 1917. From 1918 to 1923 he was in the Bureau of Agricultural Economics, U.S.D.A. In 1923 he joined the department of agronomy of Pennsylvania State University, first in extension, soon in research on the production of turf and the breeding of turfgrasses, receiving the title professor of agronomy in 1937. From 1942–45 he was in the U. S. Air Force, retiring as Lieutenant-Colonel. His work concerned turfgrass production for the control of dust and wind erosion on the many U. S. Air Force installations in the United States.

He is responsible for the isolation and introduction of Pennlawn creeping red fescue, Pennlu creeping bentgrass, a vegetative strain, and Penncross creeping bentgrass, a synthetic seed strain. He is one of the leaders in turfgrass research in the United States and is author of the well known textbook, "Turf Management". He has pioneered many advances in this field.

He was chairman of the Turfgrass Division of the American Society of Agronomy in 1952, has been a member of its committees, and has presented many papers on Society programs.

WERNER L. NELSON

WERNER L. NELSON was born at Sheffield, Ill., in 1914. He received his B.S. degree from the University of Illinois in 1937, the M.S. degree in soil chemistry from the same institution in 1938, and the Ph.D. degree in soil physics from Ohio State University in 1940. He taught soils one year at the University of Idaho before joining the staff of the North Carolina Agricultural Experiment Station in 1941. Since that time he has worked in various phases of soils research and teaching, becoming professor of agronomy in 1947.

He has studied fertilizer and lime requirements, fertilizer placement, rotation effects, and plant row spacing. He has also taken an active part in the use of radioactive phosphorus as a tracer in fertilizer research. In 1949 he became director of the soil testing division of the North Carolina Department of Agriculture. Since 1951 he was in charge of soil fertility research, North Carolina State College. Dr. Nelson was appointed midwest manager, American Potash Institute, Lafayette, Indiana, in October, 1954.

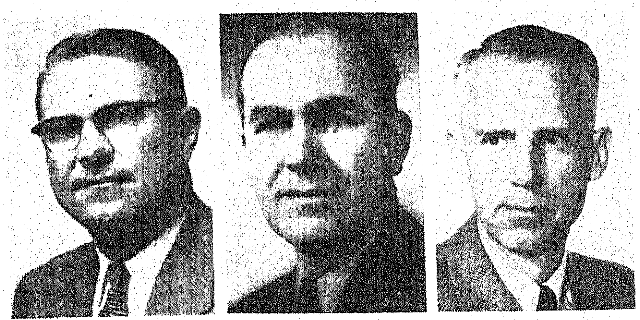
Dr. Nelson is chairman of Division IV—Soil Fertility, Fertilizers, and Plant Nutrition—of the Soil Science Society of America. He has been a member of a number of national committees including chairman of the Committee on Fertilizers and Chairman of the National Soil Test Work Group. He was chairman of Division IX at the International Soil Science Society Meetings in Dublin, Ireland, in 1952.

JOHN M. POEHLMAN

JOHN M. POEHLMAN was born near Macon, Mo., in 1910. He received the B.S. degree in 1931, and the Ph.D. degree in plant physiology in 1936 from the University of Missouri. Since then he has been on the staff of the University of Missouri, becoming professor of field crops in 1950. He was granted leave of absence 1943–44 to serve as associate agronomist, Division of Rubber Plant Investigations, located at Belle Glade, Fla.

Dr. Poehlman is widely known for his success in breeding improved varieties of small grain crops. Missouri O-205 oats and B-400 barley, both widely known, are products of his skill in plant breeding. Winter barley in Missouri recently increased to 500,000 acres and it is estimated that 85% is B-400. Missouri 0-205 oats are recommended and grown in 12 states, occupying a huge acreage.

He is author or joint author of 30 publications dealing with the production and breeding of small grains. His broad knowledge of this field qualifies him to serve as a member of the National Oat Council and of the North Central Technical Committee on oats and wheat.



Nelson Poehlman Richards

In 1950 Dr. Poehlman was granted 2-months leave of absence to study plant breeding methods in France, Belgium, Holland, Denmark, Sweden, and England. During his European tour he appeared on the program at the International Botanical Congress in Stockholm, Sweden.

Dr. Poehlman has been a member of the American Society of Agronomy since 1934, regularly attending and participating in the program at annual meetings.

Dr. Poehlman has always been deeply interested in teaching and students. Since joining the staff in 1936, he has taught or assisted in most of the courses offered in his department. He helped organize the Agronomy Club for students interested in crops and soils, and served as an advisor to it until recently.

STERLING J. RICHARDS

STERLING J. RICHARDS was born at Fielding, Utah, in 1909. He received the B.S. degree in soil physics at Utah Agricultural College in 1933, and the Ph.D. degree at Cornell University in 1938.

He then went to the New Jersey Agricultural Experiment Station, where he stayed until 1948, with time out during 1942 to 1945 as associate physicist and physicist in the engineering laboratories of the Signal Corps, U. S. War Department. In 1948 he joined the staff of the Citrus Experiment Station, University of California at Riverside, where he is now vice chairman of the department of irrigation and soils, and associate irrigation engineer.

He has published a considerable number of articles in *Agronomy Journal* and the *Soil Science Society of America Proceedings*, and contributed a chapter to the A.S.A. monograph, "Soil Physical Conditions and Plant Growth". He has attended the Society meetings regularly throughout his professional career, and has been associate editor of the *SSSA Proceedings* for the past three years, reviewing its papers on soil physics.

ROBERT R. ROBINSON

ROBERT R. ROBINSON was born near Point Marion, Pa., in 1909. He attended the University of West Virginia, obtaining the B.S. degree in 1931 and the Ph.D. degree in 1936. During 1931–35 he was a part-time agent with the Division of Forage Crops and Diseases, U.S.D.A. From 1931 to 1937 he was on the staff of the Division of Forage Crops and Diseases in investigations on the fertilization and management of pastures in West Virginia. In 1937 he was transferred to the U. S. Regional Pasture Research Laboratory at State College, Pa., and has served there since.

Dr. Robinson has been particularly concerned with investigations of the interrelations of soil moisture, soil fertility, and pasture management in grassland improvement. He and his associates have shown some of the possibilities as well as limitations of supplemental irrigation of grasslands in the Northeast. He has made important contributions to our knowledge of factors affecting persistence of perennial legumes. He has studied the environmental factors conducive to germination of hard seed of Ladino clover in the soil, in relation to natural reseeding of Ladino clover.

He has been a member of the American Society of Agronomy and the Soil Science Society of America since 1936. For the past 5 years he has been secretary-treasurer of the Northeastern Branch of the Society.

HAZEL L. SHANDS

HAZEL L. SHANDS was born in 1908 at Landrum, S. C. He received the B.S. degree in agriculture at Clemson College in 1929, and the Ph.D. degree in plant breeding and plant pathology at the University of Wisconsin in 1932. Since that time he has been engaged in cereal crop breeding and instruction at the University of Wisconsin and is presently professor of agronomy.

Dr. Shands has been concerned with the oat improvement, and the varieties for which he has been primarily responsible have been and are widely grown in the North Central states. He has made many contributions to the technical literature in his field, and has participated actively in promotion and development of cooperation with other workers and with industry.

He has been a capable and effective teacher of both beginning and advanced students.

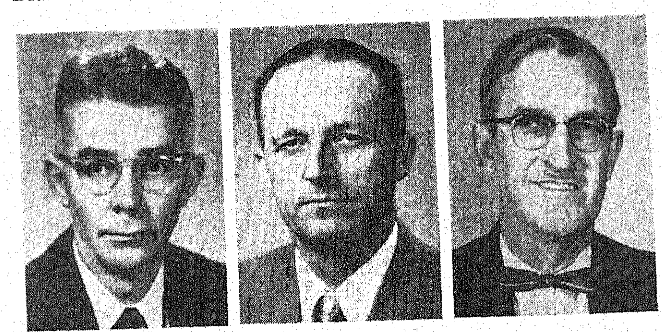
COIT A. SUNESON

COIT A. SUNESON was born at Missoula, Mont., in 1903. He obtained the B.S. degree from Montana State College in 1938 and the M.S. degree from Kansas State College in 1930. He joined the U. S. Department of Agriculture staff as a junior agronomist in July 1930 and was stationed at the University of Nebraska for about 6 years. He was then transferred to the University of California and has continued there to the present time.

Professor Suneson has had a productive career in the science as well as practice of plant breeding. He is author or co-author of nearly 80 publications which attest to his productiveness as a scientist. He has also been very successful as a plant breeder. Wheat varieties which he had a prominent part in the development of include Pawnee, Poso 42, Big Club 43, Baart 46 and Onas 53. The Poso 42 and Big Club 43 are Hessian fly resistant varieties and Baart 46 is an improvement over Baart 38 in rust resistance. Onas 53 is an awned variety which is resistant to race 15B.

Professor Suneson has also had a prominent part in the selection of Rojo, a smooth awned barley which is resistant to yellow dwarf virus.

Professor Suneson served as vice president of the Western Branch of the American Society of Agronomy in 1948–49.



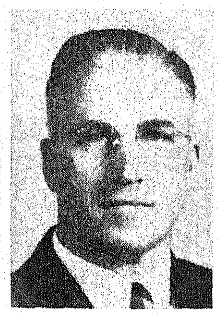
Robinson Shands Suneson

EDWARD H. TYNER

EDWARD H. TYNER was born in Chicago, Ill., June 15, 1907. He received his B.S. degree in agriculture at the University of Nebraska in 1930 and his M.S. and Ph.D. degrees in soils at the University of Wisconsin in 1932 and 1934, respectively. He served as instructor in soils at the University of Nebraska in 1934–35, as assistant soil scientist with the U.S.D.A. in North Dakota in April to November, 1935, as professor of soils at North Dakota State College in 1935–1938, and as assistant professor and associate professor of agronomy at the West Virginia University from 1938 to 1950 when he accepted his present position as professor of soil fertility at the University of Illinois.

Dr. Tyner's research has been in the field of soil chemistry and plant nutrition. He has published more than 20 technical papers and several popular articles and circulars, and has directed the thesis research of several M.S. and Ph.D. candidates. His work on foliar analysis as a diagnostic tool in soil fertility evaluation represents a major contribution, and his work on the regeneration


Tyner


Volk


Woodruff

of strip-mine spoil has aided in the quantitative understanding of the processes of soil formation. He has served for several years as an associate editor of *Soil Science Society of America Proceedings.*

GARTH W. VOLK

GARTH W. VOLK was born in 1905 near Oconto Falls, Wis. He received the B.S. degree in 1934, the M.S. degree in 1935 and the Ph.D. in 1936 from the University of Wisconsin with a major in soil chemistry and minors in chemistry, mineralogy, and plant physiology.

After 4 years of university work, Dr. Volk worked for the United Fruit Co. in Central America as a soil chemist and on land exploration from June 1928 to September 1933, when he returned to Wisconsin for graduate work. He was assistant professor of soils at Oklahoma Agricultural Experiment Station and Oklahoma A. & M. College from July 1, 1936 to Feb. 1, 1938. He then went to the Alabama Agricultural Experiment Station, where he was made professor of soils in 1942. In 1944 Dr. Volk became associate soil chemist at the Ohio Agricultural Experiment Station and was appointed chairman of the department of agronomy at both the Ohio Agricultural Experiment Station and Ohio State University in 1947.

Dr. Volk conducted research on soil porosity, water movement in soils, soil nitrogen, and analytical methods for soil analysis at the Oklahoma Agricultural Experiment Station. He was in charge of all phosphorus research at the Alabama Agricultural Experiment Station for 6 years and specialized in work on potassium and lime at the Ohio Agricultural Experiment Station. He taught practically all the usual elementary soils courses.

He has been a member of the American Society of Agronomy and the Soil Science Society of America since 1936. He has presented a number of papers at the Society meetings, has served as chairman of the Soil Chemistry Division, and on many Society committees. He was president of the North Central Branch of the Society in 1953.

CLARENCE M. WOODRUFF

CLARENCE M. WOODRUFF was born in Kansas City, Mo., in 1910. He received the degrees B.S., M.A., and Ph.D. from the University of Missouri in 1932, 1935, and 1953, respectively. From 1932 to 1938 he was employed by the Soil Conservation Service at the Erosion Experiment Station at Bethany, Mo. In 1938 he was appointed instructor in soils at the University of Missouri, and was appointed associate professor of soils there in 1954. During the war years, 1942–46, he was radio engineer, U. S. Air Corps.

He has been an active member of the Society for over 20 years. He was chairman of the Division of Soil Technology, has attended most meetings, and taken part in the programs. He has been a member of the editorial board committee of the *Soil Science Society of America Proceedings* serving as an associate editor for 3 years.

The Forty-Seventh Annual Meeting of the American Society of Agronomy

THE forty-seventh annual meeting of the American Society of Agronomy was held Aug. 15–19 on the campus of the University of California College of Agriculture at Davis, Calif. The general business session was called to order by Pres. G. G. Pohlman on Monday afternoon, Aug. 15. Following annual reports from the Society's central office and from standing and special committees, H. R. Wellman, vice president for Agricultural Science, University of California, delivered an invitational address, "Public-supported Research in Agriculture."

Pres. Pohlman delivered the annual presidential address, "The Hills of Home," an historical survey of agriculture in the Appalachian area, at the annual banquet Wednesday evening, Aug. 17. Winners of the student essay contest were announced by Henry Foth; the outstanding student chapter award was presented by R. M. Swenson to Duane Swarts, president of the University of Illinois Field and Furrow Club; and the Society Fellowship elections for 1955 were announced by C. J. Willard.

The annual business meetings of the Soil Science Society of America and the Crop Science Society of America, and the Agronomic Education Division were held Tuesday, Aug. 16. More than 300 papers were presented at the meetings of the 13 divisions of the Societies.

Special meetings held conjointly with the Societies were: Fertilizer Application Program; Western Alfalfa Improvement Conference; and Military Land Use and Management.

1955 REPORT OF EXECUTIVE SECRETARY

On Sept. 30, 1955, the total membership (all classes) stood at 2,832 compared to 2,609 on Sept. 30 one year ago. This represents an increase of 223 members, in the active membership class, since the number of associate and sustaining members showed a very slight decline (see table 1).

In terms of active members only, the totals were 2,542 on Sept. 30 this year compared to 2,314 on the same date a year earlier. This is an increase of very close to 10%, the largest recorded in the recent history of the Society. Also, for the first time in the history of our Society, our total of active members has passed the 2,500 mark.

This year, for the second time, our Society conducted a special membership drive during May and June. This campaign is probably the main reason for the splendid increase in Society membership registered this year. A prize, consisting of a $50 U. S. Treasury Bond was offered to the active member in each Regional Branch who obtained the greatest number of new membership applications between May 1 and June 30. We are pleased to report that all Regional Branches had a winner in this year's contest. They are as follows: S. M. RALEIGH, Northeast Branch; H. D. FOTH, Southern Branch; F. T. GARDNER, North-central Branch; and R. E. DANIELSON, Western Branch. These four members have earned a real vote of thanks from the officers and members of the American Society of Agronomy.

At our Davis meetings, we presented some figures on which states have shown the largest increases in membership during the 12 months ended July 31, 1955. Among those states with 50 or more active members a year ago, Minnesota showed the top gain of 34%, Iowa gained 22.3%, and New York increased 20.5%. Among all states which gained 5 members or more, Idaho led the way with a gain of 46%, Kentucky was second with 44%, and Utah was third with 41%.

We would like to congratulate the members in these six states for their membership achievements, and also for showing us what can be accomplished when our members get out and work for a stronger Society.

There are two new names on our list of sustaining members this year, the Middle West Soil Improvement Committee and the Smith Agricultural Chemical Co. We wish to welcome both of these fine organizations and to thank them for their splendid support.

PUBLICATIONS

All three of our periodical publications have made satisfactory gains in circulation since our report to you as of Sept. 30, 1954. The total paid circulation of *Agronomy Journal* rose from 2,797 to 2,956 during the 12-month period. This net gain of 159, the largest recorded in recent years, represents an increase of 71 in member subscribers and an increase of 88 in non-member subscribers (see table 2).

During the same period, the paid circulation of *What's New in Crops & Soils* was increased by 885 subscribers, reaching a new high level of 15,027 paid subscribers as of Sept. 30, 1955 (see table 3). During the 12-month period ending Sept. 30, 1955, our office sold 12,326 new and renewal subscriptions for this publication.

SSSA Proceedings likewise made good progress, going from 1,840 paid subscriptions on Sept. 30, 1954, to 2,045 on the same date in 1955. This net gain of 205 included an increase of 147 in member subscriptions and 58 in non-member subscribers (see table 4).

All three of our periodical publications showed satisfactory financial progress during the fiscal year ended Sept. 30, 1955. *Agronomy Journal* had net earnings of $16,687 compared to $17,090 one year ago. *Soil Science Society Proceedings* had net earnings of $3,255 compared to $4,085 during the same period 1 year earlier. *What's New in Crops & Soils* showed a small loss of $845, compared to a loss of $1,497 one year ago. Thus, all three periodicals continue in good financial health.

FINANCIAL PROGRESS

A comprehensive report by the Budget and Finance Committee appears in this same issue of the *Journal,* so we will not be repetitious. However, we would like to point out that the net earnings of $23,815 for the 1954–55 fiscal year are almost identical to those of the previous fiscal year, which showed $23,673. For the fiscal year just passed, net income after commissions totalled $150,910 with total expenses of $127,094. As of Sept. 30, 1955, the sum of $12,000 was transferred to earned surplus reserves of the American Society of Agronomy ($10,000) and the Soil Science Society of America ($2,000). On Sept. 30, 1955, the total assets of the American Society of Agronomy, including SSSA, stood at $144,026 and the net worth was $64,814. Both of these figures represent substantial gains over those shown in the same categories on September 30, 1954.

LOOKING AHEAD

At the 1955 annual meetings of the Society held at Davis, California, we reported the need for additional personnel at the Central Office here in Madison, since we have been short-handed both in the editorial and clerical departments. Since those meetings, the budget and finance committees and the Executive Committee of the Board of Directors has authorized us to employ (1) an assistant editor for technical journals, who will also help in the publication of future volumes in the Monograph Series, and (2) an IBM clerk-typist trained in the operation of the Executive Model of this machine, who will also help in our membership work and in the production of the forthcoming ASA news bulletin. The addition of these two workers will not only solve some of our present problems in the Central Office, but will also enable us to take on the additional work load already assigned.

One of our more urgent needs at the present time is additional space for storing back issues of the various publications. We have a total of approximately 1,800 square feet in office space at the present time, and it would take approximately 600 square feet more to accommodate the large stock of back issues still being stored at the W. F. Humphrey Press in Geneva, N. Y. There is no additional storage or office space in our building at the present time. If some should become available during 1956, we will seek authority from our Executive Committee to obtain it for Society use.

The following paragraphs contain a few items that may tend to increase the strength and effectiveness of our Society's program in the years ahead.

Many of our members feel that the number of papers presented at our annual meeting each year is much too large, making the convention resemble a 7- or 8-ring circus. It is our suggestion that more of the papers dealing with local problems and those of limited interest be assigned to state and regional meetings rather than the national ASA meeting.

In connection with Regional Branches, some members have suggested that there should be more of them not only to reduce the amount of travel required for attending them, but also to permit

Table 2.—Paid circulation of *Agronomy Journal* on Sept. 30, 1954 and Sept. 30, 1955.

Date	Total circulation	Member subscribers	Non-member subscribers
Sept. 30, 1954	2,797	1,489	1,308
Sept. 30, 1955	2,956	1,560	1,396
Gain or loss	+159	+ 71	+ 88

Table 3.—Paid circulation of *What's New in Crops & Soils* on Sept. 30, 1954 and Sept. 30, 1955.

Date	Paid circulation	Total distribution
Sept. 30, 1954	14,142	15,032
Sept. 30, 1955	15,027	16,213
Gain or loss	+ 885	+1,181

Table 4.—Paid circulation of *SSSA Proceedings* on Sept. 30, 1954 and Sept. 30, 1955.

Date	Total circulation	Member subscribers	Non-member subscribers
Sept. 30, 1954	1,840	1,242	598
Sept. 30, 1955	2,045	1,389	656
Gain or loss	+205	+147	+ 58

Table 1.—Membership totals for ASA (including SSSA) on Sept. 30, 1954 and Sept. 30, 1955.

Date	Total memberships (all classes)	Active members		Associate members	Sustaining members
		ASA only	ASA & SSSA		
Sept. 30, 1954	2,609	1,013	1,242	295	59
Sept. 30, 1955	2,832	1,096	1,389	290	57
Gain or loss	+223	+ 83	+147	—5	—2

two meetings each year instead of one. Perhaps there should be a New England Branch, a Pacific-Northwest Branch, an Inter-Mountain Branch, a Northern Plains Branch, and so on.

The several State Sections that are affiliated with our Society have grown very nicely and have demonstrated their usefulness. We hope that there will be more State Sections in the years ahead.

We also like the idea of special meetings and top-ranking symposia every year. Several have been held in recent years, and virtually all of them were unusually successful.

The matter of additional publications and awards is being studied by appropriate committees of the Society, and we are looking for some good recommendations from them in the near future.

The staff of the Central Office greatly appreciates the support and encouragement given it by officers and members of the society during the past year. With continued help of this kind, we feel sure that much progress can be made during the year ahead.—L. G. MONTHEY.

ASSOCIATE EDITOR, WHAT'S NEW IN CROPS & SOILS

My report is concerned with the Editorial problems in publishing *What's New in Crops & Soils*. There are of course many questions with which we are confronted in the central office at Madison. I am going to confine myself to two points which I believe should be emphasized at this meeting. These are, first, the need for more editorial material with which to fill each issue of the magazine, and second, the matter of reader interest.

On the first point, the amount of material required, I want to give you some figures about the number of items which went into Volume 7 of *What's New in Crops & Soils*. This takes in the nine issues published in the last year: October 1954 through August–September 1955. The 9 issues in this volume contained 58 feature stories. These are the articles which required one or more pages of space in the magazine. Volume 7 included 812 separate news items. It contained 302 photographs. There were also 144 advertisements.

I go into this simply to indicate the size of the job in publishing *Crops & Soils*. This is a cooperative effort. As your employees, we could not begin to do this job alone and without your help. The magazine is what it is because many of you are putting in time and effort in getting information to us, and in keeping us informed at all times on what is transpiring agronomy-wise throughout the country. It takes a large flow of material to keep the magazine coming out regularly. We are dependent upon you who are getting that material to us for processing and for incorporation into the magazine.

The information which is published and which represents the Society when *Crops & Soils* goes into a reader's home comes from those of you who are willing to write. If you do not write and if you do not send us items, we cannot publish those items in *Crops & Soils*. This means that much good agronomic information may go unreported. I would like to urge that those of you who haven't been contributing to *Crops & Soils* consider that possibility. The wider the contributing base from which we can draw for editorial material, the better the magazine, and in turn the better the job it can do for the Society and for you as a member.

The second point concerns an editorial problem. This is a thing with which every going magazine must contend. *Crops & Soils* is no exception, and it seems we are up against this matter in one form or another at all times. The problem is one of keeping readers interested. *Crops & Soils* has more subscribers than ever before, some 15,000 at the present time. These people must be kept happy every month. If they aren't kept happy, they don't renew their subscriptions. There is very little chance of getting them back, once they are lost.

Mr. C. J. LEWANDOWSKI, our circulation manager, summarizes the renewal percentage every month. These renewals are an index to the interest the magazine holds for subscribers. We are much concerned about this matter of reader interest at all times. The need for emphasis on reader interest is sometimes hard to explain to those of you who write for *Crops & Soils*. It is the reason we place so much emphasis upon short sentences, on short words, on simple concepts, and on devices which add color to your articles. It is the reason we spend a considerable amount of time in working over many of the articles which come to us. I want to express the hope that those of you who have done and are doing so much in contributing to *Crops & Soils* will be patient with us when we use a heavy editorial hand on your articles. The reader of a magazine is a stern disciplinarian.

These two problems which I have mentioned are troublesome only as they stand in the way of a better magazine. All of us, whether contributors or editors, need to give some thought to them. *Crops & Soils* is coming along successfully. Continued effort to get more thorough coverage of agronomic information sources and putting more stress on reader interest will make the magazine an increasingly valuable and indispensable servant of the Society.

MAURICE R. HAAG

MANAGING EDITOR—AGRONOMY JOURNAL

This report covers recent *Agronomy Journal* operations, which are essentially the same as those for the previous report period. In the past 12-month period, the *Journal* received 139 full length articles and 27 notes. Thus far, this calendar year (January 1 to August 15), we have published 87 articles and 24 notes. And manuscripts received to date this year total 87 full length articles and 19 notes. This is running slightly behind last year, and the interval between receipt and publication is more or less stabilized at 5 months. Earlier this year a few articles were published only 3 months after we received them, and 1 was published 12 months after receipt, showing how the time lag is influenced by the speed of review and revision as well as by the number of manuscripts received.

A divisional breakdown of the 87 articles published through August this year is as follows:

Genetics and Cytology, 23; Physiology and Ecology, 19; Crop Production, 21; Seed Production, 5; Weeds and Weed Control, 1; unclassified soils papers, 10; agronomic education, 4. This is not a clear picture since it is not broken down vertically by specific subject matter. We also published 4 invitational papers, 4 varietal registrations, and the Soil Science Society fertilizer sub-committee report on changing fertilizer guarantees from the oxide to the elemental basis.

There is a slight increase over last year in the number of soils papers. The still small number published is counterbalanced with respect to the Society's over-all interests by the 125 articles published in *Soil Science Society of America Proceedings*.

The *Journal's* reviewing procedure was severely criticized in 2 instances, this year, one for alleged inadequacy, the other for captious criticism. Since there was probably some justification for it in each case, I am sure that the criticism merely demonstrates practical and human limitations of the *Journal's* reviewing procedure. With that, I again presume to speak for the membership in thanking the associate editors and reviewers for their indispensable and invaluable work.

Late this year or early in 1956, we expect to issue a manual for contributors to the *Journal* and *Proceedings*. As a comprehensive revision of the booklet issued by Mr. Luckett in 1948, it will include instructions for preparing charts, graphs, photographs, and tables, a formula for estimating the length of an article, and other suggestions which, we hope, will help us all. We are preparing it for our own good as much as for your help, and hope that it will help enhance the typographical and editorial quality of the *Journal* as well as the quality of the *Journal* contents. When it is ready for free distribution, we will publish a notice in the *Journal* and *Proceedings*.

DONALD E. GREGG

BUDGET AND FINANCE

The Budget and Finance Committee of the American Society of Agronomy held a joint meeting with the S.S.S.A. B.&F. Committee in Madison on Oct. 28 and 29, 1955.

At this meeting, financial statements for the 1954–55 fiscal year were studied, and a proposed budget for the 1955–56 fiscal year was prepared for the consideration of the A.S.A. Board of Directors.

Financial reports of the Society for the 1954–55 fiscal year reflect satisfactory progress, with net earnings comparable to those achieved in the two preceding fiscal years. As evidence of this progress during the past fiscal year, we present the following three reports:

Table 1. Statement of Assets and Liabilities of the American Society of Agronomy (including S.S.S.A.) as of Sept. 30, 1955.

Table 2. Summary of Changes of Net Worth by Project, Sept. 30, 1955.

Table 3. Condensed Statement of Assets and Liabilities by Project, Sept. 30, 1955.

It can be pointed out that the actual expenses for the 1954–55 fiscal year closely approximate the budget estimates for that year, except in the case of convention expenses for the 1954 and 1955 annual meetings, both of which took place in the fiscal year ending Sept. 30, 1955. Further, it is gratifying to note that A.S.A. income (for all projects) exceeded budget estimates by approximately $12,000.

Continuing the practice of recent years, the Budget and Finance Committees recommend that at least $10,000 of A.S.A. earnings be transferred to the A.S.A. Earned Surplus Reserve Fund as of Sept. 30, 1955, and further, that this amount be invested in savings and loan association stock. It is also recommended that $2,000 of the Soil Science earnings for 1954–55 fiscal year be transferred to S.S.S.A. Earned Surplus Reserve Fund and be invested in a similar manner.

As of Sept. 30, 1955, the total A.S.A. Earned Surplus Reserve Fund invested in U. S. Treasury Bonds, savings and loan associations, and bank saving certificates totaled $42,000, excluding the $10,000 increment recommended above. On the same date, total S.S.S.A. Earned Surplus Reserve funds invested totaled slightly over $10,000, excluding the additional $2,000 referred to above.

The joint meeting of the A.S.A. and S.S.S.A. Budget and Finance Committees reaffirms the importance of continuing to build an earned surplus reserve in both A.S.A. and S.S.S.A. until an adequate fund is established. In the opinion of these committees, the total is still far short of that necessary to guarantee the financial stability of these organizations.

During the 1954–55 fiscal year, the A.S.A. Endowment Fund was increased by $5,800 through the sale of 58 sustaining memberships. This fund now totals $18,994 (as of Sept. 30, 1955).

The satisfactory financial situation reflected in the past year's operation is due largely to increased sales of subscriptions, advertising space, memberships and miscellaneous services. The increased sales were largest in the case of individuals and institutions not classed as members of the societies.

The situation regarding *What's New in Crops & Soils* continues to be encouraging. The deficit of $845 incurred in the past fiscal year is the smallest since this educational magazine was launched. It continues to carry a substantial percentage of the overhead and general service costs incurred by the central office.

Table 1.—American Society of Agronomy (including SSSA) statement of assets and liabilities Sept. 30, 1955.

Assets		
Cash—First National Bank	$24,599.49	
Cash—Randall State Bank	60,628.42	
Savings account	1,090.93	
Petty cash	50.00	
Total cash items		$ 86,368.84
Bank Savings Certificates	$ 9,000.00	
U. S. Savings Bonds—Series J	32,848.00	
Shares—Savings & Loan Associations	10,175.37	
Total investment items		52,023.37
Postage inventory—meter		307.68
Postage deposit—second class		399.80
Advances—Agronomy Career Circular		334.62
Accounts receivable		4,592.00
Total assets		$144,026.31
Liabilities		
Accounts payable	$ 546.27	
Withholding tax payable	403.46	
Social security reserve (F.I.C.A.)	86.24	
ISSS—Dues collections	37.00	
Emil Truog Award account	2,287.66	
Deferred subscriptions	31,579.91	
Earned surplus reserve—ASA	34,000.00	
Earned surplus reserve—SSSA	10,271.63	
Total liabilities		$ 79,212.17
Net Worth		
SSSA—Division V	$ 1,200.00	
Soil Science Society of America	19,753.26	
American Society of Agronomy	24,866.88	
Endowment Fund—ASA	18,994.00	
Total net worth		64,814.14
Total liabilities and net worth		$144,026.31

The proposed budget for the current fiscal year (1955–56) is, we believe, realistic in expense estimates and conservative in the estimate of anticipated income. This budget, which will be recommended to the Board of Directors for their further action, is presented herewith.

PROPOSED BUDGET FOR AMERICAN SOCIETY OF AGRONOMY

(and Soil Science Society of America), 1955–56.

Schedule A. Estimated total income and expense, Oct. 1, 1955 to Sept. 30, 1956, inclusive:

Source of Income	Total	Crops & Soils	Agronomy Journal	SSSA Proceedings	Society Service
Subscriptions, members'	$ 26,000.00	$———	$15,000.00	$11,000.00	$———
Subscriptions, general	68,500.00	37,000.00	22,500.00	9,000.00	———
Sales: single copies and back issues	2,400.00	300.00	900.00	1,200.00	———
Sales: reprints	9,500.00	1,000.00	5,000.00	3,500.00	———
Sales: advertising space	20,200.00	16,000.00	3,500.00	700.00	———
Membership dues	15,500.00	———	———	———	15,500.00
Investment income	1,000.00	———	———	———	1,000.00
Miscellaneous items	2,400.00	2,000.00	100.00	100.00	200.00
Total Estimated Income	$145,500.00	$56,300.00	$47,000.00	$25,500.00	$16,700.00
Less: Commissions payable	4,000.00	2,300.00	1,200.00	500.00	———
ESTIMATED 1955–56 INCOME	$141,500.00	$54,000.00	$45,800.00	$25,000.00	$16,700.00
Less: Estimated Expenses	130,070.00	53,253.00	31,357.50	24,724.00	20,735.50
Profit or Loss, 1955–56	$ 11,430.00	$ 747.00	$14,442.50	$ 276.00	$(4,035.50)*
Less: Earmarked for Reserve and Pension Fund	10,000.00	———	10,000.00	———	———
NET EARNINGS (estimate)	$ 1,430.00	$ 747.00	$ 4,442.50	$ 276.00	$(4,035.50)*

Schedule B. Estimated breakdown of expenses, Oct. 1, 1955 to Sept. 30, 1956, inclusive:

Nature of expense	Total	Crops & Soils	Agronomy Journal	SSSA Proceedings	Society Membership Service
Production:					
Engraving, mailing, postage, printing, paper, and supplies	$ 63,550.00	$25,350.00	$20,800.00	$16,850.00	$ 550.00
Salaries, including clerical	13,544.50	5,551.00	4,177.50	2,760.00	1,056.00
Distribution and promotion:					
Postage, printing, paper, supplies, circulation audit, and refunds	10,325.00	9,325.00	—	—	1,000.00
Salaries, including clerical	15,986.50	6,706.00	3,201.50	2,138.00	3,941.00
Administration and general services:					
Office expense, supplies, rent, maintenance, insurance, and travel	10,900.00	3,500.00	1,600.00	1,600.00	4,200.00
Organizational membership in the Policy Committee for Agricultural Societies	300.00	—	—	—	300.00
Salaries, including clerical	15,464.00	2,821.00	1,578.50	1,376.00	9,688.50
TOTAL ESTIMATED EXPENSES	$130,070.00	$53,253.00	$31,357.50	$24,724.00	$20,735.50

* ( ) denotes minus balance, or excess of expense over income.

Table 2.—Summary of changes in net worth by project as of September 30, 1955.

American Society of Agronomy and Soil Science Society of America

	Totals	Crops & Soils	Agronomy Journal	ASA Service	ASA Endowment Fund	SSSA Service & Proceedings	SSSA Division V	Marbut Memorial
Sept. 30, 1954—Balance	$47,755.28	$(11,459.15)	$19,926.68	$ 7,496.35	$13,194.00	$16,840.63	$—	$1,756.77
Add								
Transfer from ASA—1954 gain	246.38	—	—	—	—	246.38	—	—
Sales—Marbut books	714.86	—	—	—	—	—	—	714.86
Collections—Endowments Fund	5,800.00	—	—	—	5,800.00	—	—	—
Transfer from Marbut Memorial	2,471.63	—	—	—	—	1,271.63	1,200.00	—
Net earnings—								
Agronomy Journal	6,686.73	—	6,686.73	—	—	—	—	—
1954 Convention	3,911.63	—	—	3,911.63	—	—	—	—
1955 Convention	1,363.59	—	—	1,363.59	—	—	—	—
Proceedings	1,254.54	—	—	—	—	1,254.54	—	—
SSSA Service	1,411.71	—	—	—	—	1,411.71	—	—
Subtotals	71,616.35	(11,459.15)	26,613.41	12,771.57	18,994.00	21,024.89	1,200.00	2,471.63
Deduct								
Net loss—A.S.A. Service	(1,967.39)	—	—	(1,967.39)	—	—	—	—
Net loss—Crops and Soils	(845.18)	(845.18)	—	—	—	—	—	—
Transfer to SSSA accounts	(2,471.63)	—	—	—	—	—	—	(2,471.63)
Transfer to Earned Surplus Reserve	(1,271.63)	—	—	—	—	(1,271.63)	—	—
Transfer to SSSA—1954 gain	(246.38)	—	—	(246.38)	—	—	—	—
Totals—before consolidation	64,814.14	(12,304.33)	26,613.41	10,557.80	18,994.00	19,753.26	1,200.00	0.00
Transfer—Crops and Soils deficit to Agronomy Journal	0.00	12,304.33	(12,304.33)	—	—	—	—	—
Totals—after consolidation	$64,814.14	$ 0.00	$14,309.08	$10,557.80	$18,994.00	$19,753.26	$1,200.00	$ 0.00

* ( ) indicates minus balance.

MONOGRAPHS AND ADVANCES

The committee is pleased to report that the fifth volume in the Monographs series was published in June. This is the long-awaited volume on "Corn and Corn Improvement," planned and edited by Dr. G. F. SPRAGUE. It is the first monograph which deals in a comprehensive way with a single crop. This is to be followed, however, by a parallel volume on oats, arrangements for which have already been made.

Two other volumes are committed. The manuscript of one, on "The Hardiness of Plants to their Environment," by Dr. J. LEVITT of the University of Missouri, is in the hands of the publisher and is scheduled to appear in the spring of 1956. The other, a co-operative treatment of the subject of drainage, prepared by a group of agronomists and agricultural engineers, under the editorship of Dr. J. N. LUTHIN, is actively in preparation.

Each year in October there appears a volume of Advances in Agronomy. Volume VII, which is to be expected on schedule this fall, contains two contributions from overseas authors. It is clear that these volumes and those of the Monographs series are reaching our professional colleagues in other countries. Almost half the copies sold now go outside the U. S., a fact which has to be recognized in the selection of topics and authors. It should be a matter of gratification to the Society that these series, which originally were planned primarily as a service to its members, are enjoying much wider recognition.

G. H. AHLGREN — R. W. PEARSON
G. W. BURTON — R. W. SIMONSON
J. E. GIESEKING — H. B. SPRAGUE
A. G. NORMAN, *Chairman*

SPECIAL COMMITTEE TO STUDY FUTURE DIRECTION OF MONOGRAPHS

General Background

In 1948 the Agronomy Society entered into a tentative agreement with the Academic Press., Inc., of New York, N. Y., to publish such monographs as may be prepared under sponsorship of the Society. A committee was appointed to determine the need for monographs, to make contacts with prospective authors and to arrange for their publication. Since the beginning, Dr. A. G. NORMAN has served as chairman of the Monographs Committee and in addition has assumed the role of Editor, working in liaison between the authors and the publisher.

Up to the present time 5 volumes of the Monograph series have been published. Tentative arrangements have been made with authors for preparation of two additional volumes. Prospects for future volumes appear good.

At the meeting of the Society at Dallas in 1953 Dr. Norman expressed his wish to be relieved of the editorial work involved in the production of the monographs. Dr. H. E. Myers, President, appointed a special committee to study the problem. The essential parts of their report, approved in 1953, are summarized below.

1. The Monograph series should be continued.
2. An arrangement should be sought with the Academic Press to provide financial support for editorial services to be performed by the Society.
3. The Society should explore the possibilities of ownership of the Monograph series when its financial reserves are adequate.
4. The Monographs Committee should be continued to provide guidance in the choice of topics for Monographic treatment.

Analysis of the Present Problem

Dr. Pohlman recognized the need for a review of the policies followed in the publication of the first five volumes in the Monograph Series. At the meeting of the Society in 1954, he appointed the present committee to make specific recommendations to be acted upon by the Board of Directors at the Society meeting in 1955.

After a study of this problem at a meeting in Madison, Wis., on July 1, 1955, the committee makes the following analysis of alternative courses of action:

Alternative 1.—No change in the present policy.

The advantages of the present system are (1) no financial risk to the Society, (2) no added editorial work for the central editorial staff, and (3) no promotion responsibilities for sales. But this alternative has many important disadvantages, including (1) an increasingly higher cost of monographs (the cost of Volume 5 is $11.50), (2) no income to the society, (3) no royalty to the authors and, most important, (4) editorial services cannot easily be secured to replace those so well and whole-heartedly given by Dr. A. G. Norman.

Committee Recommendation.—The present arrangement with Academic Press be terminated with the publication of Volume 5. In making this recommendation we recognize that although the Society has received no direct financial return, it has received indirect benefits from the publication of the first five volumes. The series has become established and recognized as a publication sponsored by our Society. The subjects given monographic treatment have been valuable additions to agronomic literature. This has been accomplished without financial risk to the Society. But from a long-range viewpoint, one of the alternatives described below would provide a more desirable policy than the one pursued in the past.

Alternative 2.—Establish a relationship with a college press—such as the Iowa State College Press—for publication of future Monographs.

The above named Press now publishes the Monograph Series for the American Society of Plant Physiologists.

The advantages of this alternative are (1) no financial risk to the Society, (2) editorial services performed by the Press, (3) cost of sales promotion assumed by publisher, (4) a 10% royalty paid to the Society, (5) members of the Society given a 20% discount on pre-publication purchases, and (6) list price may be somewhat lower than previous volumes with equal or better quality as judged by costs of its publications.

The disadvantages of this alternative include (1) authors receive no royalty, (if Society receives royalty), (2) income to the Society is limited and determined solely by a fixed percentage on sales, and (3) the discount to members would eliminate entirely the usual 10% to ASA on all copies sold to members.

Alternative 3.—Establish a relationship with a college press—such as the University of Wisconsin Press—for publication of future Monographs.

In this plan the Society would provide editorial services, aid in promotion of sales and receive financial returns for its contributions to the production and sales efforts by sharing 50–50 in the net profits from each volume.

The advantages of this alternative are (1) income to the Society could be higher than in Alternative 2—especially for highly saleable volumes, (2) editorial services would be provided by our own specialized staff, (3) members of the Society would be given a discount price, and (4) cost of production would be lower because the Press staff is subsidized by the University of Wisconsin.

The disadvantages of this alternative are (1) the Society would need to expand its present editorial staff to handle the added duties, and (2) The Society must guarantee the cost of production.

Alternative 4.—The Society assume all costs as publisher, including production, editing, sales promotion, and distribution.

The advantages of this alternative are (1) probable income to the Society may be greater than alternatives 2 or 3, (2) cost per volume to members should be lower because sales promotion costs would be less, (3) editorial services would be provided by our specialized staff, (4) added editorial staff (1 man) would be available for other expanded Society programs leading to greater efficiency in assignment of personnel to specialized duties such, for example, as an editor for *Proceedings* and soils Monographs, and an editor for the *Journal* and crops Monographs, and (5) the purposes of the Society and the limitation of Federal Tax Laws could be more satisfactorily met by publication of scientific books than by accumulation of a large endowment or reserve fund.

The disadvantages of this alternative are (1) greater financial risk to the Society and (2) present Society assets would be tied-up in inventory stock of unsold books rather than in securities. This could be an advantage when viewed on the basis of interest rates on inventory *vs.* securities.

Committee Recommendations on Alternatives 2, 3 and 4

It is the recommendation of this committee that the Board of Directors give first priority to *Alternative 4.* In reaching this decision we have considered the recommendations made by the committee report in 1953, the present financial reserves of the Society, the probable earnings from these reserves and the future needs for editorial services in the Society Headquarters.

A cost analysis of undertaking the production of the Monograph Series is given in table 1, based on the following conservative considerations:

1. Sale price per copy, $7.00.
2. Production output—1 volume per year.
3. Sales per volume—2,000 copies, of which 1/3 will be sold the first year and 1/4 of the remainder in each of the next 4 years.
4. Cost of production, $4.90 per copy including printing (letterpress), editing, royalties (10%) to authors, overhead, mailing and shipping, storage, and sales promotion. (Based on data from college presses).
5. Inventory value, $4.90 per copy.

Table 1.—Production costs, income, and inventory values.

	Production cost	Sales income	Inventory value	Cash gain or loss
First year				
Volume 6	$9,800	$ 4,669	$ 6,532	−$5,131
Second year				
Volume 7	$9,800	$ 4,669	$ 6,532	
Volume 6	———	2,333	4,900	
Total	$9,800	$ 7,002	$11,432	−$2,798
Third year				
Volume 8	$9,800	$ 4,669	$ 6,532	
Volume 7	———	2,333	4,900	
Volume 6	———	2,333	3,263	
Total	$9,800	$ 9,335	$14,695	−$ 465
Fourth year				
Volume 9	$9,800	$ 4,669	$ 6,532	
Volume 8	———	2,333	4,900	
Volume 7	———	2,333	3,263	
Volume 6	———	2,333	1,637	
Total	$9,800	$11,668	$16,332	$ 868
Fifth year				
Volume 10	$9,800	$ 4,669	$ 6,532	
Volume 9	———	2,333	4,900	
Volume 8	———	2,333	3,263	
Volume 7	———	2,333	1,637	
Volume 6	———	2,333	———	
Total	$9,800	$14,001	$16,332	$4,201
Sixth year	$9,800	$14,001	$16,332	$4,201

From the data given in table 1 it is apparent that financial gains to the Society would not be realized until the fourth year and that much of our present cash reserves would be converted into inventories in the first three years. On the assumption that all books are sold, the earnings from inventories would be considerably greater than the present earnings from securities.

The additional time of one extra member to the editorial staff could be more advantageously used if more than one volume could be produced annually, or if additional publications (such as the proposed Crop Variety Register or an Agronomy Handbook) were initiated. The Variety Register or Agronomy Handbook would be revised as needed and thus become a recurring publication.

Alternative Recommendation.—If the Board of Directors feels that the Society should not initiate the above plan at present, the Committee recommends that Alternative 2 or 3 be followed. In either Alternative 2 or 3, the Society and its members would be better served than by the procedure now followed. It is recognized that in Alternative 3 we would essentially guarantee the cost of production, do much of the work, but only share in expected profits.

R. J. Muckenhirn L. G. Monthey
I. J. Johnson, *Chairman*

AWARDS 1955

This committee was appointed by President Pohlman in accordance with the action of the Board of Directors at the 1954 meeting. It has given consideration to two problems: (1) the desirability and feasibility of developing an Award Program for recognizing outstanding achievements made to agronomic science and practice, and (2) the general policies under which this program might be established.

Some of the problems that have been raised relative to the granting of awards are as follows:

1. The difficulty of selection of recipients on an equitable basis, especially in a society as large as ours, representing many specialized areas of work.

2. The undue publicity or recognition that may be received by the commercial concern or individual who provides the funds for the awards in comparison with the recognition received by others who contribute in other important ways to the Society's program.

3. The restriction sometimes placed by donors relative to the administration of the awards.

In the past the Society has administered two grants for the specific objective of providing awards to Society members. These were (1) a grant from the Chilean Nitrate Soda Educational Bureau made in 1928 for Nitrogen Research Awards and (2) a grant from Dr. and Mrs. W. H. Stevenson in 1947 for the Stevenson Awards.

At the present time, however, the Society makes no awards to individuals for outstanding contributions.

In its study of this problem, the committee has had the benefit of examining correspondence by the Board of Directors, the Executive Secretary of the Society, and others. It has also studied the policies on awards of other scientific societies. It is the considered judgment of this committee that the granting of a reasonable number of awards by the Society in recognition of outstanding achievement is desirable. It is believed that this can be accomplished equitably and without undue cost to the Society. The following are the committee's recommendations:

1. That the Society establish a positive, continuing program of awards. One of the chief purposes of this program would be to recognize outstanding members of the Society who have made outstanding contributions in research, teaching and extension.

These awards could be made for the time being from the earning of the ASA Reserve Fund if they were limited to $150 each annually.

2. That as soon as feasible, the Society establish an Awards Fund to which individuals, firms, associations, and other groups could contribute for the support of the Society Awards Program.

It is suggested that the minimum contribution to this fund be $500 and that the names of all contributors each year be listed in the Society program and in its official publications.

It is the belief of this committee that the establishment of an Award Fund should not and would not compete with or jeopardize the sustaining membership program of the Society.

3. That it be the policy of the Society not to accept grants for the recognition of a particular individual, for establishing graduate fellowships and assistantships, nor in support of specific research. It is believed that such grants and recognitions can best be made as at present through the land-grant colleges and other research and teaching institutions.

4. If the Society moves forward on a positive, continuing program, the Committee suggests that a detailed statement of principles and procedures be prepared for the administration of the Awards Program.

In the preparation of this statement of policy and procedure, careful studies should be made of the procedures developed by other scientific societies, particularly with respect to the procedures used in the selection of recipients. It is believed that a system of canvassing and of making nominations similar to that established by the American Chemical Society would insure a high degree of discrimination in the selection of recipients, one of the most important factors in the success of an Awards program.

B. R. Bertramson H. H. Kramer
L. A. Dean A. O. Kuhn
W. H. Pierre, *chairman*

PUBLICATION NEEDS

The committee was unable to meet during the year but opinions regarding publication problems and needed changes were exchanged by correspondence. In addition, the committee had available comments from several other society members and officers. Many divergent viewpoints have been expressed. These are summarized as follows:

1. Make no changes at least at the present time.
2. Establish a new journal for publication of technical crops papers (to be called *Proceedings of Crop Science Divisions, Jour-*

nal of Crop Science or other suitable name). In this case the *Agronomy Journal* would remain the official society organ and would contain papers of general interest and those that are on the borderline between technical crops and technical soils. The *SSSA Proceedings* would continue to carry the technical soils papers.

Similar to this is the suggestion of establishing a publication series, identical in format, such as is now found in the *Canadian Journal of Research*.

3. Establish a *Plant Breeding Journal*. All other crops papers, papers of general interest, and combination crops-soils papers would continue to be carried in *Agronomy Journal* which would remain the official organ of the ASA.

4. Make the *Agronomy Journal* the official organ of the Crop Science Divisions and restrict its use to publication of crops papers. To serve as official organ of ASA, carrying news and items of official nature, a new bulletin, similar to the AIBS bulletin, would be established. It has been suggested that such a bulletin might also carry abstracts of papers presented at national, regional and local meetings.

5. Have one publication, divided into three sections of four issues each. One set of four issues would carry soils papers, another crops papers, and the third general and intermediate papers.

In attempting to evaluate these alternative proposals, certain information is pertinent. A number of people have suggested that *Agronomy Journal* has become almost exclusively a crops journal and that almost all papers in it deal with crop breeding. To provide some tangible evidence, the types of papers carried in 1949, 1950, 1953 and 1954 have been summarized.

Percent of papers of various kinds carried in the Agronomy Journal in 1949, 1950, 1953 and 1954.

Papers	1949	1950	1953	1954
Crop Breeding	43	36	40	49
Other Crops	34	29	29	31
General and Intermediate	12	12	12	14
Soils	11	23	18	6

No doubt others would not agree with the classification of some of the papers. Nevertheless, the summary is believed to present a fairly good picture. First, a majority of the papers deal with crops and there has not been a marked change in percentage during the four years sampled. Second, less than half of the papers deal with crop breeding. Third, the percent of soils papers in 1954 is low, but, considering the fluctuation in the other three years, it might be unwise to conclude from these data that there is a definite trend away from soils papers. If there is a trend away from soils papers in the *Journal*, it is certainly not the result of deliberate editorial policy.

With regard to number of subscriptions and net earnings, the publications of the society are now in a sound position. For the year ending Sept. 30, 1954, there were 2,797 subscriptions to *Agronomy Journal* and net earnings (i.e. excess of income over expenses) were $17,090.38. For the *SSSA Proceedings* there were 1,840 subscriptions and $4,085.62 net earnings.

There was on hand for the *Agronomy Journal* at the end of the year 1954 (see *Agronomy Journal* 46, p. 590) a six months supply of manuscripts. This number does not seem to be excessive. A journal must have some backlog to insure meeting of the publication deadlines. H. E. Myers (letter of March 12) points out that there is an excess of soils papers that will require enlargement of the *SSSA Proceedings* if all are to be published there.

Judging from this, there would appear to be few available papers that are not now being carried by *Agronomy Journal* or *SSSA Proceedings*. *Agronomy Journal* is the primary medium in this country at present for publication of crops papers, including those on crop breeding and excepting those published in the *Weed Journal* and *Journal of Range Management*. Establishment of a *Crop Science Journal* would likely not cause many more crops papers to be submitted to Society publications. We would seem, therefore, to have to deal at present with the technical papers now being published in *Agronomy Journal* and *SSSA Proceedings*.

From the viewpoints expressed by various committee members, it is apparent that the most prevalent sentiment, but by no means a unanimous opinion, was in favor of the first alternative, i.e., that no change in publication procedure be made at this time. Reasons for maintaining status quo are as follows:

(1) Publications of the Society are now in a sound financial condition and are carrying most or all of the acceptable papers submitted by members for publication. So far as can be determined, manuscripts have not been rejected because of excess publication load. Nothing should be done that would jeopardize the financial condition of the present publications.

(2) The *Agronomy Journal* is an old and widely known journal. It would be desirable, if at all possible, to retain it as a strong medium for scientific publication.

(3) Establishment of a *Crops Science Journal* in addition to the *Agronomy Journal* and *Proceedings* would further divide the membership and reduce the number of subscriptions, thus perhaps jeopardizing the financial position of *Agronomy Journal* while not providing a sound basis, subscription-wise, for the new crops journal.

(4) There are not enough papers to supply three technical journals unless additional papers will be attracted by the revised publication setup.

(5) There may in fact be a trend toward the *Agronomy Journal* becoming purely a crops publication so far as technical papers are concerned. As one man pointed out, we may in a few years have a crops journal, *de facto*, if we don't try too hard now to solve the problems. When that occurs, it may be desirable for the Society to consider whether the *Agronomy Journal* (as such or under a new name) should be continued as its official organ or whether a new publication (such as the AIBS bulletin, for example) is needed.

(6) What has been said regarding problems created by establishment of a *Crop Science Journal* applies even more strongly to establishment of a *Plant Breeding Journal*. Less than half of the papers in *Agronomy Journal* are on plant breeding. There would not be enough plant breeding papers for a good journal unless a substantial number of papers could be drawn from other sources. Furthermore, member subscription would likely be limited almost entirely to the plant breeders.

Those who favor a change along the line of one of the several alternatives point out the following:

(1) There is an increasing trend toward specialization in research and toward increasing separation of the Society into divisions and, perhaps, into two societies. Our publication program, based as it is on earlier concepts of organization of the ASA, should be brought up to date in conformity with the growth of the Society.

(2) It is not very logical for the official organ of the ASA to carry only or largely technical papers from one segment of the membership of the Society.

(3) A member of the SSSA, who wishes to subscribe to the official organ of the ASA, must take a journal that carries few technical papers of interest to him.

(4) We should recognize events as they occur. *Agronomy Journal* is now, and has been for several years, largely a crops journal. Why continue to maintain officially that it is a joint publication?

(5) The SSSA has an official publication in the *Proceedings*. Therefore the crops group, especially if a Crop Science Society is organized, should also have an official publication. It is interesting that the crops members of our committee seem to be less concerned about this matter than are the soils members.

In view of these considerations, the committee recommends that no change be made at this time in the Society's publication program and that the problem be reviewed periodically in future years with the thought that some change may become necessary or desirable.

Since this is a majority but not a unanimous recommendation and since some members of the committee urge further study of the problem, the Directors may wish to continue the present committee during the next year.

M. L. Peterson	A. G. Norman
H. M. Tysdal	D. F. Beard
L. A. Richards	T. H. Rogers
H. E. Myers	H. B. Sprague

W. M. Myers, *chairman*

PUBLICITY

The national Publicity Committee of the American Society of Agronomy, composed of Zenas Beers of the Middlewest Soil Improvement Committee, W. H. Garman and M. H. McVickar of the National Plant Food Institute, Maurice Haag of the American Society of Agronomy, and myself, has functioned in much the same pattern as established for the last two meetings during which Mr. Beers served so capably as chairman.

This meeting has posed a few new problems, in that it is a campus meeting and somewhat removed from the news service centers, making it more difficult for representatives of press and radio to cover the meetings personally. However, the press, radio, and TV people have been widely contacted by mail and a goodly number are present now.

Publicity planning and policy for this conference has been a function of the national committee, worked out in close liaison with the A.S.A. headquarters in Madison and coordinated with the local Public Relations and Press Committee, headed by Dr. C. A. SUNESON. The work of the local committee is very important because most of the coverage on a meeting of this type is local in nature. Dr. Suneson and his assistants have done an outstanding job. As I mentioned before, the task has been a little more difficult this year because the meeting site is somewhat removed from a metropolitan area.

The meeting will also receive considerable national publicity. Several representatives from the national farm magazines are in attendance. One and possibly two of the national wire services will be represented. Again this year, NBC is producing a half-hour kinescope show built around this meeting to be used on its National Farm and Home Hour.

Besides the great contribution made by Dr. Suneson and his local group, the lion's share of the publicity work this year has been done by Larry Monthey and Maury Haag in the A.S.A. headquarters office. They have sent out a lot of material to press and radio representatives, and have worked out a multitude of details for a smooth functioning operation. I know that the headquarters office has prepared over 100 news releases on the many technical papers that will be presented. This is a real service to news writers and broadcasters, as these are scientific papers intended for scientific consumption. The news significance to the average person depends upon interpretation of the papers through releases that bring out the important points in a readable and convenient form. In this regard, I am sure that the Society would want me to thank all the speakers who cooperated so well by sending in their abstracts.

Now for a few personal thoughts on the future responsibilities of the Publicity Committee. The committee, as now constituted with representatives from commercial organizations with the chairman being from one of these organizations, was organized in 1953. It served first during the Dallas meeting. The results of this approach, as expressed in terms of coverage received in newspapers, magazines, radio, and TV, has been extremely good. Certainly this theory of operation has been justified without qualification. I believe it has served another purpose. It has emphasized the need for concentrated publicity activities, continuing year-round activities by the Society.

In fact, it is my feeling that emphasis on these activities has reached the point where they could best be served if the over-all publicity organization be placed under the direction of staff personnel of the A.S.A. headquarters office, both actually and titularly. In other words, I am recommending that the chairman of this committee be not someone from a commercial organization but a staff member of the headquarters office. As far as the annual meeting is concerned, this would mean that the high degree of cooperation from a local committee would have to be continued. With the fine editorial talent I have observed in college extension offices during the past 3 years, and their willingness to help out, I am sure that this is no problem.

I would recommend that industry representatives continue to hold membership on the committee and I am sure they will be more than willing to help out in an advisory capacity and with their own area of interests and contacts. Personally, it has been a thoroughly enjoyable experience serving on this committee, and the American Seed Trade Association Board of Directors has wholeheartedly supported our participation.

There is no other organization in existence with a membership that devotes its time and scientific talents more to the basic needs of society than does the membership of the American Society of Agronomy. The public ought to be told what they are doing. Thoughts expressed here are directed to that end.

WILLIAM HECKENDORN, *chairman*

LOCATION AND TIME OF MEETING

The Society has previously approved recommendations of this committee that the meeting in 1956 be held in Cincinnati, Ohio, November 12–16; the meeting in 1957 in Atlanta, Ga., Nov. 18–22; the meeting in 1958 in Madison, Wis., August 25–29 on the campus of the University of Wisconsin; and the meeting in 1959 in Cincinnati, Ohio, Nov. 9–13.

In conformity with the recommendation of the Board of Directors of the Society on Nov. 20, 1952, the Committee on Location of Meetings should recommend at this time a meeting site for 1960.

The Society on Nov. 8, 1954 at St. Paul, Minn., approved general policies to be followed by the committee in recommending a meeting site. These policies are:

1. That fall meetings, Oct. 20 to Dec. 20, be held at least 3 years out of every 4 and that not more than 1 summer meeting be held every 4 years.
2. That 50% of the meetings be held in the area between Cincinnati, Ohio, and Kansas City, Mo., with the remaining 50% to be held farther east and farther west.

2a. That 3 or 4 key cities with outstanding facilities should *not* be set up as regular meetings locations.

In conformity with these policies the committee recommends that the 1960 meeting be held in *Denver, Colo.*, from *Oct. 31 to Nov. 4.*

S. R. ALDRICH	H. T. ROGERS
I. M. ATKINS	F. W. SLIFE
H. B. CHENEY	R. S. WHITNEY

H. E. JONES, *chairman*

STUDENT ACTIVITIES SECTION

We are happy to have the opportunity to make an annual report of the Student Activities Section to the members of the Society. We are sure that all of you are aware that today's members of the Student Activities Section will be tomorrow's agronomists. For this reason, we feel you are interested in their activities and progress of the past year.

Membership

During the past year the Agronomy Clubs at the Alabama Polytechnic Institute and Oregon State College petitioned for and were accepted as members of the Student Activities Section of the American Society of Agronomy. This makes a total of 40 clubs which are now affiliated with the national organization.

Activities

This is the fourth year of the National Agronomy Achievement Award Contest for the selection of the best student Agronomy Club in the United States. The judges for this year's contest were Dr. H. K. WILSON, Pennsylvania State University, chairman; Dr. H. E. MYERS, Kansas State College, and Professor F. D. KEIM, University of Nebraska. The winner will be announced at the Annual Dinner Meeting Wednesday evening. The winning club will be presented a beautiful trophy and check for $100 to help with the delegates' expenses by the National Plant Food Institute.

Dr. V. C. FINKNER of the University of Kentucky, chairman of the Student Essay Committee, reports that a total of 59 essays were written this year. Some of the essays were eliminated in local contests. Thirty essays from 15 different institutions were submitted to the National Contest; 3 were disqualified, leaving 27 for final rating. The essays were judged by members of the Student Essay Committee consisting of members of the parent society and a representative of the editorial staff of *What's New in Crops and Soils*. Winners of the contest will be announced Wednesday evening. The American Potash Institute is giving valuable support to this contest by contributing funds to be used for the awards and to provide travel expenses for the three top winners to attend the meetings of the society. *What's New in Crops and Soils* will award 1-year subscriptions to each of the top 10 winners and will pay $25 for each essay published regardless of placement in the contest. We feel that you as members of the American Society of Agronomy should put forth more effort to encourage the students at your institution to participate in this very worthwhile contest.

S. M. RALEIGH of Pennsylvania State University, chairman of the National Crops Judging Committee, reports that 11 student teams competed in each of the contests at Kansas City and Chicago last fall. He asked me to report that there is plenty of room for other teams to enter the contests.

One National Agronomy *Newsletter* was prepared and distributed by the National Corresponding Secretary. Another edition will be prepared shortly after these meetings.

Registration for the meetings is incomplete. The first meeting of the Student Section will not be held until this evening. We hope that many of the western clubs which haven't been able to attend the eastern meetings will be represented this year.

The National Student Officers this year are:

President, LESTER SCHMIDT, University of Minnesota
Vice-President, BOYD STUHR, University of Nebraska
Recording Secretary, JAMES HASENBECK, Oklahoma A & M College
Treasurer, JACK McDANIEL, University of Arkansas
Corresponding Secretary, KENNETH MUNKRES, Kansas State College

All of our meetings are being held in Room 176 of the Home Economics Building. We extend to all of you an invitation to attend any or all of the meetings.

In conclusion we would like to report that the clubs throughout the country are in various stages of activity and we ask you as members of the parent society to give a little extra personal encouragement to the students at those institutions where the clubs are not too active. We are convinced that activity in a well organized club gives the student training which will be of value to him all his life.

H. D. FOTH, *vice-chairman*
R. M. SWENSON, *chairman*

AGRONOMIC MANPOWER RESOURCES

During the year the committee made arrangements with the American Institute of Biological Sciences and the National Science Foundation for circularizing the Society membership with questionnaires relative to obtaining information for the National Register of Scientific and Technical Personnel. The Central office of the A.S.A. has distributed the questionnaires. The completed questionnaires will be analyzed by the AIBS and the NSF and data and findings made available to the Society. The only costs involved to the Society are those of mailing out the questionnaires. It is urged that every member complete the questionnaire so that the tabulations will be representative for the Society.

Results from the Register may be used as background material for government policy decisions concerning scientific and technical personnel. Information obtained from data collected in 1951 by the AIBS for the Register has been recently published by the National Science Foundation in a report entitled "Manpower Resources in the Biological Sciences".

The Chairman attended the Feb. 4, 1955, meeting of the Scientific Manpower Commission as a representative of the Policy Committee for Scientific Agricultural Societies. Legislation pending in Congress relative to scientific manpower problems was the chief topic for discussion. Details relative to this legislation are presented in the report for the Policy Committee for Scientific Agricultural Societies by Dr. W. H. GARMAN.

"A Statement of Policy Relating to Specialized Personnel" was published in the Agronomy Journal 47:197–198, 1955 by the committee.

Work is going forward as reported at the last meeting on the preparation of a register of agronomy graduates. A proposal is in preparation outlining a procedure for preparing such a roster. This roster will supplement the National Register of Scientific and Technical Personnel, for it will include the new agronomy graduates omitted in the Register. Such data in conjunction with the Register can be used in a number of ways, as for example, in scientific manpower studies of the National Science Foundation it could provide a basis for estimating the future needs for agronomists.

W. A. ALBRECHT	L. N. SKOLD
J. B. PETERSON	W. H. LEONARD
K. H. KLAGES	S. A. TAYLOR

C. L. W. SWANSON, *chairman*

GRASSLAND IMPROVEMENT STEERING COMMITTEE

A subcommittee is working on Grazing Land Census Procedures to formulate questions that may be used by the U. S. Census Bureau in 1960. It has become increasingly evident that agronomists may be of aid in evaluating land use because they possess the broad background essential in an integration of soil and water use, climatic adaptation, transportation, marketing, and the customs of the farm people.

On the basis of the meeting in St. Paul and of subsequent correspondence, it is recommended that symposia of specific topics relative to forage evaluation be scheduled on the program of the annual meetings of the American Society of Agronomy. It is recommended that representatives of the Divisions of Cytology and Genetics, and Crop Production and Management take active part in the symposia and that representatives of the Animal and Dairy Science Societies be invited to participate.

The subject suggested for one of the symposia would include specific problems relative to production of forage with improved quality. The problem of providing such forage throughout the year should be clarified. Storage problems of forage as hay and silage and the expected losses in dry matter and changes in quality should be presented and discussed.

Another problem that warrants attention is that of evaluating new species or strains of grasses and legumes. It should be decided whether tests should be with pure stands or as combinations of grasses and legumes, also, which management practices will be of greatest aid in selecting superior plants for different uses with results expressed in terms of quality and seasonal distribution of production as well as yearly dry matter yield.

R. B. ALDERFER	O. E. SELL
F. V. BURCALOW	H. B. SPRAGUE
S. J. RICHARDS	V. G. SPRAGUE, *chairman*

INTERSOCIETY COOPERATION

No new activities were undertaken by this committee during the year. Its major accomplishment consisted of spearheading the organization of the Policy Committee for Scientific Agricultural Societies, and seeing this new group into official being.

It appears as though timing will be favorable during the coming year for the anticipated and needed study of possible avenues of cooperation among societies for the purpose of reducing overhead and publication costs. The Policy Committee for Scientific Agricultural Societies affords an appropriate mechanism for conducting cooperative intersociety studies.

Activities for the 1954–55 year were concerned primarily with cooperation with the Scientific Manpower Commission. This area of the committee's activity is covered in the report of the A.S.A. representative to the Policy Committee for Scientific Agricultural Societies.

It is recommended that the A.S.A. Committee on Intersociety Cooperation be disbanded, and that the president and the executive secretary of the American Society of Agronomy be delegated to advise with the A.S.A. representative on the Policy Committee for Scientific Agricultural Societies.

R. M. LOVE	R. W. SIMONSON
L. G. MONTHEY	C. L. W. SWANSON
H. C. MURPHY	W. H. GARMAN, *chairman*

FIRST ANNUAL REPORT OF A.S.A. REPRESENTATIVE POLICY COMMITTEE FOR SCIENTIFIC AGRICULTURAL SOCIETIES

This committee offically came into existence on Jan. 31, 1955, culminating nearly 2 years of activity on the part of the committee on Intersociety Cooperation. The following scientific agricultural societies participated, and became formal members, with official representatives as follows:

American Society of Animal Production—JOHN E. FOSTER
American Dairy Science Association—L. A. MOORE
American Society of Agricultural Engineers—TRUMAN E. HIENTON
American Society of Range Management—B. W. ALLRED
American Society of Agronomy—W. H. GARMAN
Soil Conservation Society of America—E. H. GRAHAM

The major activity of this new body has been to gain official recognition as a nominating agency for the Scientific Manpower Commission, and to have two representatives elected to membership in the Commission.

For the past 12 months the broad field of agriculture has had, for the first time, a voice in manpower problems of concern to the defense of this Nation.

Our first two representatives of the S.M.C. were TRUMAN E. HIENTON, of the U. S. Department of Agriculture, representing the fields of soils and agricultural engineering, and MARVEL E. BAKER, Associate Director of the Nebraska Agricultural Experiment Station, representing the animal sciences. They were elected

by the Commission in August 1954. In April Mr. Baker accepted an assignment with the Foreign Operations Administration in Turkey, and since that time the animal science groups have been represented on the Commission by JOHN E. FOSTER, of the University of Maryland.

Dr. Foster's term will expire Dec. 31, 1956, and Dr. Hienton's on Dec. 31, 1955. The societies composing the Policy Committee are currently engaged in submitting nominations for a successor to Dr. Hienton. This successor will be elected in time to be seated with the Commission at its annual meeting in October (1955).

Review of SMC Activities

As in 1952–53, a major concern of the Scientific Manpower Commission has been the military status of scientists. This concern extended to problems of deferment, utilization of scientific personnel in the armed forces, and legislation relative to selective service and reserve obligations. Although there has been no change in policy relative to scientists in uniform, the Commission has taken an active part in placing many inductees in the Specialized and Professional Personnel Program and in this effort has received excellent cooperation from the Army. Of greater importance is the revision of the Department of Defense policy. Upon the insistence of the Commission, the Office of the Defense Mobilization Committee on Specialized Personnel has taken a review of the Specialized and Professional Personnel Program.

Relations with the Selective Service System have improved during the past year. A year ago there was a heavy drain on graduate students, science teachers, and industrially employed scientists. Since January, Selective Service headquarters have ruled favorably upon 95% of the cases that the Commission has placed before it.

The easing up of the situation is due to the fact that the military manpower pool has become quite large, plus the fact that present military needs do not require more than one-half to two-thirds of our physically and mentally fit young men. Under these conditions, it is logical to expect that more serious attention will be given to the scientific and technological needs of the nation.

The 84th Congress was faced with the need of extending the regular draft and the doctors draft, both of which expired June 30, 1955. Arguments by the executive director of the S.M.C. in support of an amendment restoring selectivity to the Selective System were ineffectual, but he did have some success in arriving at a shorter period of liability for scientists and engineers who had been deferred for professional work.

It is hoped that the proposed National Reserve Plan bill will contain a provision whereby young men with scientific training may fulfill their military obligation by entering a 6-month training program, and thereafter serving in the military reserve. Should this measure be enacted into law, the scientific manpower situation would be substantially improved. It would mean that young scientists and engineers serving in critical occupations and essential activities would be withdrawn from their work for 6 months instead of 24 months. It would reduce the drain on the specialized personnel in the military manpower pool by 75%. (Since this report was prepared, the National Reserve Plan has been enacted into law.)

As your representative on the Policy Committee for Scientific Agricultural Societies, I wish to assure you that in view of our large national manpower pool, the present activity of the Scientific Manpower Commission in bringing about a reduction in the time liability of individuals engaged in critical occupations is truly a step in the direction of strengthening the defense of our Nation.

Policy Committee

The sum of $650.00 was contributed to the Scientific Manpower Commission by the Policy Committee toward the activities of the Commission in 1955. There is a possibility that in 1956 the Commission will not need to call upon its nominating agencies for financial support.

In the Policy Committee for Scientific Agricultural Societies, agricultural scientists today have a body on a par with those in other areas, such as chemistry and biology. Prior to the organization of this committee, however, agricultural scientists lacked any sort of official body which might be called upon to consider national problems affecting their members.

Today the member societies of PCSAS feel that they have an effective organizational setup, and thereby a means of taking under consideration with a minimum of effort and delay any problems which concern individual scientists or groups of scientists in the broad field of agriculture. It might be added that this committee, as it is now organized, will require practically no overhead operational costs. A deposit of $75.00 was made to the credit of the Policy Committee in the McLachlen National Bank of Washington, D. C., on March 15, 1955. This sum was provided by the American Society of Agronomy for the purpose of meeting routine expenses. To date it has not been necessary to make any charges against this deposit.

W. H. GARMAN

ENDOWMENT FUND

The Endowment Funds Committee is pleased to report that as of this date we have 57 sustaining memberships. Although this is two less than one year ago it is very gratifying to know that we are holding this type of membership so well. Actually we lost four and gained two new memberships. The prospects are good as regards gaining a few additional memberships during the coming year. The receipts from this type of membership are all being kept in a special Endowment Fund which now totals approximately $25,000.

The support the Society is receiving from industry and various organizations connected with agronomic matters is very gratifying and heartening, indeed. May I again suggest to the members of our Society that they express due appreciation for this support by giving reasonable service at all times in helping sustaining members with their numerous problems.

Special mention should again be made of the invaluable help which Mr. L. B. MONTHEY has rendered in connection with the work of the Committee.

L. E. ARNOLD	W. HECKENDORN
F. E. BEAR	W. H. PIERRE
B. R. BERTRAMSON	G. D. SHERMAN
R. COLEMAN	F. B. SMITH
W. E. COLWELL	J. R. TAYLOR, Jr.
H. J. HARPER	E. H. TYNER

E. TRUOG, *chairman*

REPORT OF THE COMMITTEE ON RELATIONSHIPS WITH THE SEED INDUSTRY

The Committee on Relationships with the Seed Industry has held two meetings with representatives of the American Seed Trade Association since November 1954. The first was on Jan. 21, 1955 at the time of the regular Winter Meeting of the A.S.T.A. in Chicago; the second on Aug. 15, 1955 in Davis, Calif.

Since the committee was appointed 3 years ago it has dealt extensively with matters relating to the turf industry. These discussions resulted in the drafting of two resolutions at the Jan. 21, 1955 meeting which emphasize the need for: *(1)* An expansion of facilities for research, teaching, and extension in the development, use, and management of turfgrasses; and *(2)* Adequate testing and evaluation of seed produced from vegetatively propagated varieties before it is distributed commercially. The complete text of each resolution follows:

1. The Joint Committee of the American Society of Agronomy and the American Seed Trade Association, meeting at the LaSalle Hotel in Chicago, Ill., Jan. 21, 1955, submits the following resolution and recommends its adoption by the parent organizations and its dissemination to all agricultural research institutions and to all administrators in research, teaching and extension services.

WHEREAS, Turfgrass work has been recognized internationally as an integral part of agriculture, and

Turfgrass work is the one agricultural enterprise in which virtually the entire urban population is intensely interested, and

It has been shown conclusively that the turfgrass business is of great value and importance, and

In many county agent's offices more than half the requests for assistance are on turfgrass problems, and

The need for further research and for accurate coordinated information and its dissemination is acute; therefore

Be it resolved, That the American Society of Agronomy and the American Seed Trade Association go on record in favor of encouraging the expansion of facilities for research, teaching, and extension in the development, use, and management of turfgrasses.

2. The Joint Committee of the American Seed Trade Association and the American Society of Agronomy meeting at the LaSalle Hotel, Chicago, Ill., on Jan. 21, 1955, recommends to the parent organizations of the two committees that resolutions be adopted by the respective organizations which will emphasize the need for expanded research to determine the value of turf grown from

seed of vegetatively propagated varieties; that such seed not be offered in commercial channels until its quality for turf production has been determined; and that in no case shall such seed be identified by variety name if the uniformity and quality of the turf is not comparable to the vegetatively propagated parent variety.

At the Joint Committee meeting held Aug. 15, 1955, it was recommended that a special sub-committee be named consisting of two members each from the seed industry and the Society to study ways and means of implementing the recommendations in the above resolutions. The appointment of the sub-committee will, of course, be dependent upon the approval of the resolutions by the membership.

Much has been gained through the joint committee meetings where there has been a free exchange of facts, ideas, and philosophies by the representatives from both the Society and the Seed Industry.

The improved relationships between agronomists and the seed industry were evident at the recent meeting of the American Seed Trade Association in Minneapolis, Minn., when two members of the Society appeared on their program. Dr. Iver Johnson of Iowa discussed "Making Progress Together" and Prof. H. B. Musser of Pennsylvania gave a paper on "Developments of New Turfgrasses and Their Potential Use." The over-all theme of the 1955 A.S.T.A. meeting was "Science in Seeds."

Last spring a representative from the A.S.T.A. appeared before Congress in support of the seed storage facilities for maintenance of valuable germ plasm. Also, state, regional, and national representatives from the Seed Industry have increased their support for research at the agricultural experiment stations either through private grants or by urging the appropriation of additional funds.

Although the work of the committee has been confined thus far to discussions relating to turfgrass, it is anticipated that, in the future, topics relating to specific turfgrass subject matter will be referred to the Society's Turfgrass Committee, while the Committee on Relationships with the Seed Industry will explore other avenues of developing better understanding and closer working relationships with the seed trade. It is through close working relationships between the many members of the seed industry and the research and applied agronomists that more effective gains can be made toward the goal of improved crop production.

The committee wishes to express its appreciation to the representatives from the A.S.T.A. for their excellent cooperation and for the arrangements they made as hosts at our meetings.

D. F. Beard	J. C. Lowery
E. N. Fergus	H. B. Musser
F. V. Grau	F. G. Parsons
J. R. Holbert	C. S. Garrison, *chairman*

REPRESENTATIVE OF A.S.A. TO DIVISION OF BIOLOGY AND AGRICULTURE, NATIONAL RESEARCH COUNCIL

Your representative attended the annual meeting of the Division of Biology and Agriculture of the National Research Council on May 13 and 14, 1955. The activities of the Division during the past year were reviewed. In addition, he has answered occasional inquiries from the Council and reviewed for it various proposals in the field of agronomy.

I have been asked to ascertain the interest of the Society in having arrangements made by the National Research Council for the collection and compilation of sources of economic plants. It is understood that a bill has been before the Congress for several years that would provide for this.

The American Society of Agronomy is one of many that have representatives in the Division of Biology and Agriculture of the National Research Council. There is little that the representative or the Society can do except when specific questions arise that are of concern to the membership. Dr. L. A. Maynard of Cornell University has now succeeded Dr. Paul Weiss as Chairman of the Division of Biology and Agriculture.

Lyle T. Alexander

A.S.A. REPRESENTATIVE, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

This year the A.A.A.S. holds it annual meeting in Atlanta, Ga. In 1956 it will be held in New York City. At the meetings this December, Section O is co-sponsoring a symposium on "Atomic Energy and Agriculture." The atomic energy relations will be discussed under the following four topics: (1) Soil-plant relationships, (2) Plant metabolism, (3) Animal metabolism and (4) Food sterilization. This should prove a very interesting program.

Another phase of the A.A.A.S. continuing program in which I am sure we are interested is their sponsoring of a Science Teaching Improvement Program. When it is realized that only 249 men and women who had prepared to teach high school physics graduated from all colleges and universities in the U. S. this spring, and that probably only about half of them will actually teach, it is seen that this is a very real problem. The A.A.A.S. is anxious to have support for this program, and a special committee of that organization has prepared a booklet outlining the problems and what might be done about them. I have several copies of this booklet, just off the press, given to me by Dale Wolfle, Executive Secretary of A.A.A.S. which I will turn over to the Chairman of the Agronomic Education Division for whatever action the Division deems desirable.

H. M. Tysdal

A.S.A. DELEGATE TO THE ANNUAL MEETING OF THE AMERICAN ACADEMY OF POLITICAL AND SOCIAL SCIENCE

The fifty-ninth annual meeting of the American Academy of Political and Social Science was held in Philadelphia, Pa., April 1 and 2, 1955. The general theme of the meeting was internal security and civil rights in America. The six sessions dealt with freedom of expression, privacy, and personal dignity, subversive persons and groups, academic freedom, job security and national security, and investigations. Sixteen outstanding speakers discussed these subjects in a very comprehensive manner.

R. B. Alderfer

REPRESENTATIVE ON THE AGRICULTURAL RESEARCH INSTITUTE OF THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

The Agricultural Research Institute is completing another active and successful year. The campaign to increase the Class A membership has been encouraging and at present there are approximately 50 such members. The increase in membership makes it possible to interest more industrial organizations in the work of the Agricultural Board and also to give more support to the Board.

The 4th Annual Meeting of the Agricultural Research Institute is scheduled for Oct. 17 and 18, 1955, in Washington, D. C. The meeting will consist of 3 half-day sessions and a banquet. Among other items to be discussed will be corn research. It is the plan to review the past, present, and future research work on this crop. A most impressive list of speakers will appear on this program. If this plan is successful, other crops or topics will be reviewed at future meetings. On one-half day, the work of the Agricultural Board will be reviewed in full, and the Projects and Proposals Committee of the Agricultural Research Institute will make its report. A prominent person will be invited to speak at the dinner meeting.

The Agricultural Research Institute works very closely with the Agricultural Board. Through a mutual exchange of suggestions, the Agricultural Board has set up three new committees, namely, Agricultural Equipment, Agricultural Pests, and Fats and Oils. These three committees are the result of suggestions developed through the Projects and Proposals Committee.

As an adjunct to the annual meeting, plans have been formulated for an international conference on the use of antibiotics in agriculture. This conference is to be held in Washington on Oct. 19–21. The Projects and Proposals Committee of the Agricultural Research Institute is participating actively in the planning of this conference which is to be conducted by the National Academy of Sciences and the National Research Council. Members of the American Society of Agronomy will find both of these meetings very interesting.

It is recommended that the American Society of Agronomy continue its cooperation with the Agricultural Research Institute.—K. S. Quisenberry.

MEETING OF PRESENT AND PAST PRESIDENTS OF THE REGIONAL BRANCHES AMERICAN SOCIETY OF AGRONOMY, AUGUST 15, 1955, DAVIS, CALIF.

All of the American Society of Agronomy regional branches were represented by one or more members. Brief reports were given on branch meetings held in 1955; well attended meetings were held by all the regional branches. The meetings of the two divi-

sions of the Western Branch were held in association with the A.S.A. meetings at Davis. For the first time, papers were presented as a part of the North-Central Branch meetings. The Northeastern Branch plans to include presentation of papers as a part of its programs in the future. With the exception of the meetings of the Southern Branch, field trips and tours designed to acquaint visitors with the host institution and its fields of interest are always a part of the regional meetings. Since the Southern Branch meetings are held in the winter months, field trips are not practical.

All the present and past branch presidents of the A.S.A. agreed that it is highly desirable that papers on subjects chiefly of local interest be presented at regional meetings. If this practice is followed, more time could be allotted for discussion periods of papers given on subjects of interest to the whole membership at the national meetings.

It was agreed that Regional Technical Committee meetings should not be encouraged to be held at the same time as the regional meetings. If it is necessary that such technical committee meetings be held in conjunction with branch meetings, then they should complete their activities either before or after the branch meeting.

There was considerable interest expressed in the possibility of publishing abstracts of the papers of regional branch meetings in one of the A.S.A. official publications.

It was agreed that the official membership of the committee of present and past presidents be composed of the present and *immediate* past presidents of A.S.A. regional branches. Other past presidents of the regional branches are invited to attend meetings of this group.

President Pohlman suggested that this group report on its activities annually, at the final meeting of the A.S.A. board of directors.

J. B. Peterson, Purdue University, was elected chairman for the 1956 meeting.

Those present at the meeting of the Present and Past Presidents of Regional Branches, August 16, Davis:

R. Bertramson	S. S. Obenshain
N. C. Brady	Warren Pope
O. E. Sell	Bert Krantz
J. F. Reed	J. B. Peterson
W. H. Pierre	D. D. Hill
G. O. Pohlman	L. G. Monthey

D. F. McAlister, *chairman*

NATIONAL JOINT COMMITTEE ON FERTILIZER APPLICATION

The National Joint Committee on Fertilizer Application held its 31st annual meeting in cooperation with the American Society of Agronomy at Davis, Calif., Aug. 15, 1955. During the morning of Aug. 15, six 30-minute invited papers were presented on the subject of "Progress in Fertilizer Application". Dr. D. G. Aldrich, Jr., University of California, vice chairman of the National Joint Committee on Fertilizer Application, presided at the sessions. The papers listed on page 7 of the American Society of Agronomy program for the 1955 meeting will be published in the Proceedings of the 31st Annual Meeting of the National Joint Committee on Fertilizer Application.

An executive luncheon meeting was held on Aug. 15 at Davis. Brief committee reports were presented, the details of which will also be published in the Proceedings.

The new officers elected for the organization are Dr. D. G. Aldrich, Jr., University of California, Davis, chairman; C. E. Guelle, International Harvester Co., Chicago, Ill., vice chairman; and Dr. W. H. Garman, National Plant Food Institute, secretary-treasurer.

Because of the merger of the National Fertilizer Association and the American Plant Food Council into the National Plant Food Institute, the latter organization will now be the representative replacing the two former organizations.

In keeping with its policy of rotating its meetings with the American Society of Agronomy, the American Society of Horticultural Science and the American Society of Agricultural Engineers, the National Joint Committee will meet jointly with the American Society of Agricultural Engineers next year in Chicago.

In addition to the National Plant Food Institute and the three scientific organizations mentioned above, the National Joint Committee on Fertilizer Application includes representatives from the National Equipment Institute and the National Canners Association.

In the present rotation system the next cooperative meeting with the American Society of Agronomy would be in Madison, Wis., Aug. 25–29, 1958.

B. A. Krantz, *A.S.A. Representative*

REPORT OF THE CROP SCIENCE SOCIETY OF AMERICA ANNUAL MEETING, DAVIS, CALIF.

COMMITTEE REPORTS

VARIETAL STANDARDIZATION AND REGISTRATION

The Committee for Varietal Standardization and Registration during the past year considered and approved for registration all field crop varieties for which applications were received. Descriptive articles for publication in the November issue of the *Agronomy Journal* are being prepared on the following varieties which have been approved for registration during the past year:

Barley: Cordova
Bromegrass: Homesteader Smooth, Lancaster Smooth, Lincoln Smooth, Lyon Smooth
Oats: Alamo, Cimarron, Floriland, Seminole, Victorgrain 48-93
Orchardgrass: Potomac
Sorghums: Greenleaf sudangrass, Tracy Sorgo
Soybeans: Capital, Dorman, Dortchsoy 67, Harosoy
Wheat: Concho, Frisco, Onas 53, Quanah
Wheatgrasses: Nordan Crested
Other Grasses: Green Stipagrass, Tualatin Tall Oatgrass

Applications for registration of the following crop varieties have been received and are presently being considered by the committee:

Alfalfa: Vernal
Soybeans: Improved Pelican

In accordance with a decision made at the 1954 meetings, the application form was revised to include the following items: (1) region of area of adaptation; (2) how extensively the variety is grown in its area of adaptation; (3) is the use of the variety increasing? Also, the applications for registration have been circulated first to the committee member responsible for the crop concerned in order that the remainder of the committee members may have the benefit of his judgment.

At the 1954 meeting it was decided to renew the practice of supplying certificates to the originating or sponsoring station or stations, and certificates for varieties approved throughout the past several years are being issued.

Changes in personnel of the committee include the appointment of Dr. E. G. Heyne to replace Dr. F. M. Briggs, who resigned from the Committee. Dr. J. F. O'Kelly also has submitted his resignation. Doctors Briggs and O'Kelly have served on this committee for extensive periods and they are commended for the fine service they have performed for the Society.

A sub-committee consisting of Doctors H. C. Murphy, chairman, E. A. Hollowell, R. E. Karper and Mr. L. G. Monthey, is studying the feasibility of this committee sponsoring the printing of a handbook listing and describing varieties of crops which have been registered.

J. O. Culbertson	I. J. Johnson
L. F. Graber	R. E. Karper
M. A. Hein	H. C. Murphy
E. G. Heyne	T. M. Stevenson
E. A. Hollowell	M. G. Weiss, *chairman*

TERMINOLOGY

At the annual meeting in 1954 this committee submitted definitions for about 50 words used in crop science and plant breeding. The acceptance or rejection of these definitions was not brought to a vote since we felt adequate time should be given the membership to study and then to voice objections if such occurred. The report of the committee was published in the *Agronomy Journal*, 46:598–599, 1954.

No objection has been received concerning the definitions of the following agronomic words and terms: (1) certified seed, (2) companion crop, (3) corm, (4) forage crop, (5) foundation seed,

(6) groats, (7) Ladino clover (pronunciation), (8) nurse crop, (9) pedicel, (10) peduncle, (11) permanent pasture, (12) perennial pasture, (13) rachis, (14) registered seed, (15) seeds, (16) seeding, (17) sow, (18) stolon, (19) supplemental pasture, (20) temporary pasture, (21) tiller and (22) tilth. The following plant breeding words and terms have not been questioned: (1) I_1, L_1, or $S_1 - S_1$ preferred, (2) heritability, (3) heterosis, (4) line, (5) polycross progeny, (6) top cross progeny, (7) recurrent reciprocal selection, (8) recombination, and (9) synthetic variety.

The following word definitions have been questioned and are either redefined in light of suggestions received, or are resubmitted by the committee in the belief that their original definition is most satisfactory.

1. *Plant nutrients:* Materials which furnish energy for growth; also elements essential for plant growth.

2. Primary and secondary roots of cereal plants:

Primary root of cereals: The root enclosed initially by the sheath-like coleorhiza together with the adventitious roots arising from the base of the first internode.

Secondary roots of cereals: Those roots which arise from the 2nd, 3rd, and other internodes below the ground surface. This extensive fibrous root system is the predominant one in the development of the cereal plant.

3. *Stand:* In populations of agronomic plants, coverage per unit area expressed either in terms of number of plants or as a percentage. (The latter is needed for grasses, especially sod-forming grasses, the former may be most meaningful for legumes.)

4. *Rhizome:* Any elongated underground stem, usually horizontal, and capable of producing leaves and roots at the nodes.

5. *Rootstock:*

(a) Same as rhizome.
(b) (In horticulture) Portion of true roots, or roots with crowns, capable of producing stems, or of having stems successfully grafted on them.

6. *Seed:*

(a) A ripened ovule with its normal coverings, and *(b)* verb meaning "to sow, as the broadcasting or drilling of small-seeded grasses and legumes without very definite placement," of 1954 report accepted but *(c)* meaning "to produce seed or go to seed" rejected.

7. *Hybrid:* The first generation offspring of a cross between two individuals differing in one or more genes.

8. *Strain:* A group of organisms of common origin having one or more definite morphological or physiological characteristics.

9. *Selection:* Any process, natural or artificial, which permits an increase in the proportion of certain genotypes or groups of genotypes in succeeding generations.

10. *Recurrent selection:* A breeding system involving repeated cycles of selection with the objective of increasing the frequency of favorable genes for yield or other characteristics.

The definition of *breeder seed* was questioned but the definition given is that used by the I.C.I.A., and this committee feels it should abide by it. The committee also feels that *crop climate* is not defined satisfactorily in the 1954 report and the definition should be dropped. The combination of words *crop climate* does not appear to be a good one, and hence no new definition is suggested. It is also recommended that the word *overseeding* be dropped.

New words submitted are defined as follows:

1. *Inoculate* (legumes): The application of Rhizobia (legume bacteria) to the seed of legume crops prior to sowing or to the soil where such crops are to be grown. (L. W. ERDMAN)

2. *Micro-climate:* Atmospheric conditions in the immediate vicinity of the plant cover and root zone.

3. *Nodulate* (legumes): The production of nodules on roots of legumes by entry and stimulation of Rhizobia. (L. W. ERDMAN)

4. *Renovation:* A procedure which includes those cultural practices that make possible the establishment of desirable legumes in grass sods without plowing. (L. F. GRABER)

5. *Specific combining ability:* A measure of the extent to which certain breeding combinations do significantly better or worse than would be expected on the basis of average performance of the crosses of the lines or clones involved.

6. *Successful inoculation of legumes:* Inoculation resulting in adequate nodulation and symbiosis between legumes and their associated bacteria. (L. W. ERDMAN)

7. *Successful nodulation of legumes:* Production of adequate numbers of effective nodules for successful symbiosis between legumes and their associated bacteria. (L. W. ERDMAN)

The committee suggests that the definitions of the words and terms of the 1954 report for which no amendments have been received be considered official with the adoption of this report. Words which are redefined here and new words and terms shall await final action at the next annual meeting. As previously, we suggest that any who have objections to the redefined words or the definitions of the new words send their comments to any member of the committee.

C. J. WILLARD C. P. WILSIE
G. H. AHLGREN, *chairman*

INTERNATIONAL CODE OF NOMENCLATURE FOR CULTIVATED PLANTS

The International Committee on Horticultural Nomenclature and Registration met in London March 23–25, 1955, to consider suggestions and criticisms of the proposed International Code of Nomenclature for Cultivated Plants. Proposals for changes in the Code were received from 15 societies, associations, and individuals, and objections to the use of the term "cultivar" from 26 American agricultural experiment stations and associations. A formal report of this meeting has been received from Dr. H. R. FLETCHER, Royal Botanic Gardens, Edinburgh, Honorable Secretary of the Committee.

With respect to application of the Code to agriculture and forestry, the report states:

"After considerable discussion, the Committee unanimously agreed—

(1) That there should be one set of rules for Horticulture, Forestry, and Agriculture. These rules should be embodied in one Code which should contain appendices relating to the naming of special groups of plants.

(2) That this Code should not be the responsibility of an International Horticultural Congress but of a special Commission.

(3) That recommendation be made to the 14th International Horticultural Congress at The Hague to the effect that in future full responsibility for the Code should be in the hands of the "International Commission for the Nomenclautre of Cultivated Plants" set up in 1948 by the Botanical Section of the International Union of Biological Sciences, and that provision should be made for full co-operation between the I.U.B.S. and F.A.O., for the reason that in certain countries the Departments of Horticulture, Agriculture, and Forestry have direct relations with F.A.O., but not with the I.U.B.S."

Those features of the Code considered controversial by agronomists are herewith enumerated and excerpts from the Committee report pertaining to these features are cited.

1. Use of "cultivar" for cultivated varieties.

The Committee directed the chairman and secretary to redraft Section B Art. C. 3. of the Code, which restricts use of the term variety to plants which occur in the wild and designates the term "cultivar" for lines and clones originated or maintained in cultivation, "to include the point that 'variety' may continue to be used instead of 'cultivar' for non-scientific purposes." The redraft, also included in the report, states in part: "It is recommended that for scientific purposes the term *cultivar* (abbreviated cv.) be applied to lines highly selected to a standard type, clones, etc., which originated or are maintained in cultivation. The term *cultivar* is thus equivalent to the English word *variety* as used in horticulture, agriculture and sylviculture ('Sorte' in German, 'sort' in Scandinavian languages). It is suggested that the current use of the term 'variety' (or any similar designation as the laws of the country require) be retained for commercial or other non-scientific purposes until such time as the term 'cultivar' may be inserted into the laws and regulations governing the commerce of the material in question." The redraft does not seem to alter the concept of the Code; it merely provides for a delay in terminology change.

2. Priority of variety names.

The portions of Section D of the Code which stipulate that the correct name of a variety is the earliest validly published or officially registered name were not altered appreciably by the Committee. As valid publication is defined by the Code as "the sale or distribution of printed or similar mechanically duplicated matter giving both the name and description or definition of the

plant concerned (with or without an illustration) or a reference to a previously published description or definition, in any language using Roman characters," agronomists fear the Code permits adoption of a correct name which might not have the approval of the originating or sponsoring research agency. Discussion on the restriction of valid descriptions to those using Roman characters was deferred for consideration by the International Commission for the Nomenclature of Cultivated Plants.

3. Designation of hybrids.

The Committee suggested no changes in Section C Art. C. 24. of the Code which recommends, "that the multiplication sign × be inserted between the generic name and the cultivar-name as a sign of hybridity." Some agronomists fear such placement of the multiplication sign will create confusion as it is normally used to separate the parents of a cross.

4. Names of reselected and improved varieties.

The Committee recommended Section J Art. C. 28. be discussed by the International Commission for the Nomenclature of Cultivated Plants. The above article states, "When a cultivar becomes through continuous selection so distinct from the original that it can be regarded as a new cultivar, it should be given a concise new name. When, however, selection has not resulted in such divergence, the reselected cultivar should bear the name of the original cultivar, linked with the name of the selector or some convenient designation." Agronomists generally contend a selected variety is either measurably different from the original, in which case it should be designated by a different name, or is not measurably different, in which case the original variety name should be required.

MARTIN G. WEISS

UNITS OF MEASURE FOR GRAIN AND SEED CROPS

The executive committee of the Crop Science Society approved the appointment of the committee on Units of Measure for Grain and Seed Crops in February, 1955. This committee has informally sampled the opinion of numerous agronomists, seedsmen, and grainmen as to the desirability of reporting yields and marketing grain or seed on a pound basis rather than on a bushel basis, as is now commonly done. Without a single exception, all of our contacts have expressed vigorous approval for such a change.

In discussing the matter with the Executive Secretary of the Minneapolis Grain Exchange, an organization representing over 500 firms or individuals concerned with marketing grain, we were informed that this group would undoubtedly enthusiastically endorse such a change as it would result in the savings of thousands of dollars of clerical work each year.

Correspondence with the executive secretary of the American Seed Trade Association indicates that the seed industry as a whole is trying to adopt the unit weight of pounds throughout its operation, and we were assured that this organization would also undoubtedly favor the change.

It has been drawn to our attention that the Grain Research and Marketing Advisory Committee recommended the following to Dr. B. H. SHAW, Administrator of Agricultural Research Service, United States Department of Agriculture:

> "*Unit of measure,* the committee reaffirms its recommendation to investigate the merits and evaluate the problems involved in shifting trade in grain from bushels to 100-pounds. This investigation should include study of the legal obstacles, institutional changes, and statistical data adjustment required in event such a change is initiated. Industry groups are urged to consider this matter and register their interest or support for such a study."

In view of the apparent widespread interest on the part of numerous individuals and organizations for a change to a pound basis, it seems desirable to consider replacing the present committee by a standing committee of the American Society of Agronomy or at least expanding the present Crop Science Society Committee on Units of Measure so that it is representative of all major sections of the country.

Some of the probable future functions of such a committee would be to:

1.—Prepare a report as to the nation-wide desirability and feasibility of a change to the pound basis and the exact measures needed to accomplish the change.

2.—Prepare a report and recommendation for action of the membership of the Society in attendance at the 1956 meetings.

3. (If the report and action are favorable)—stimulate nation-wide interest in the change. Cooperate with and, if necessary, assume leadership in coordinating the efforts of all interested groups so as to reach the desired goal.

H. H. LAUDE H. C. MURPHY
E. H. RINKE, *chairman*

MEMBERSHIP

This committee was appointed by President Stringfield on April 11, 1955, with Dr. A. O. KUHN, University of Maryland, as chairman. It has not been possible for the committee to have a meeting. There has been an exchange of correspondence relative to some of the problems pertaining to the function of such a committee. Dr. Kuhn relinquished the chairmanship of this committee as of mid-July when he was appointed assistant to the president of the University of Maryland. For the balance of the period prior to the meetings. J. R. COWAN carried on as temporary chairman.

The primary goal of this committee would be to obtain more members for C.S.S.A. In striving for such a goal it would seem important to place emphasis on obtaining members who have a definite interest in the work of the Society and who would endeavor to make the Society a better organization. It would not seem logical to measure the value of any Society entirely on the basis of the number of members; however, a Society must be constantly alert to new phases of work and serving. It is also important and logical in a dynamic science such as the work now represented by the C.S.S.A. that each and every year there should be a re-evaluation of the performance of the Society in relation to its memebrship. The committee is in agreement that such a philosophy is the one that should be adopted.

In effecting such a goal it will be important to contact all prospective members in as orderly and systematic manner as possible. Such prospects will wish to know what such a society would have to offer them. In addition to verbal salesmanship there could well be a place for an appropriate pamphlet or brochure stating the aims and objectives of such a Society. In order to effectively reach all these prospects, there should be a network of canvassers. This might be organized on a state basis with a committee in each state to function as the canvassing unit. The mechanics of such an operation will be one of the primary tasks of this committee. Such an organization should be somewhat similar to that of the S.S.S.A. There should at least be a close liaison between the two committees of these two societies.

It is quite possible that some consideration should be given to a publication, particularly for the C.S.S.A. The committee is not in agreement as to the approach that might be taken here. In some cases it is felt that the *Agronomy Journal* is quite adequate. In other cases the opinion was expressed that the *Agronomy Journal* might be taken over as a crops publication. And in other instances it was suggested that there be a publication known as *Proceedings* to somewhat parallel the similar publication put out by the Soil Science Society of America. This committee feels that it should work very closely with the publications committee under the chairmanship of Dr. William Myers, relative to the adoption, if any, of a new publication for the Crop Science Society of America.

It is recognized that such groups as the defense agronomists, weed men, those interested in conservation, the grassland area, and others have an interest in the American Society of Agronomy. It is quite possible that such persons could be interested in becoming active in the C.S.S.A. It would appear that one of the obligations of the membership committee would be to determine how the C.S.S.A. might function to be of assistance and interest to these particular groups.

It would be the recommendation of this committee that the C.S.S.A. instruct a membership committee during the coming year to study carefully the necessary machinery for a complete canvass or contact of potential members. It would seem that such a committee should also work closely with the publications committee to determine what might be done to further the interests of those in C.S.S.A. along such a line. Also it is extremely important that such groups as the defense agronomists, weed research, conservation, grassland, and those interested in other such divisions of agronomy be contacted and determine their interests in such a society.

R. P. MURPHY R. C. ECKHARDT
F. P. GARDNER J. RITCHIE COWAN, *temporary chairman*

TURFGRASS COMMITTEE (FINAL REPORT)

Resolution

The 1955 Turfgrass Committee meeting during the business session of Division XI, on Wednesday, Aug. 17, 1955, approved the following resolution:

WHEREAS, Turfgrass Management has achieved international recognition as an integral part of agriculture, and

WHEREAS, Turfgrass Management has gained Divisional status in the Crop Science Society of America of the American Society of Agronomy, and

WHEREAS, it is believed that the original objectives of the Turfgrass Committee have been attained, therefore,

Be it resolved that, The Turfgrass Committee request permission to submit a final progress report and be discharged with obligations fulfilled.

THE TURFGRASS COMMITTEE
FRED V. GRAU, *chairman*

This resolution was accepted by the Executive Committee of the Crop Science Society on Thursday, Aug. 18, 1955.

In response to requests for a brief history of the Turfgrass Committee the following report from 1946 is included here:

FURTHER PROGRESS IN THE SCIENCE OF TURF

"The meetings of the American Society of Agronomy and the Soil Science Society of America were concluded at Columbus, Ohio, on March 1, 1946, with some significant developments for Turf. With the unanimous backing of research men at experiment stations in 20 states, the Crop Science Divisions of the American Society of Agronomy was asked to establish a Turf Section and to appoint a permanent Turf Committee. Both requests were unanimously granted. This action now establishes a direct link between the leading agronomic science organizations in the U. S. and the various phases of applied turf management. Greenkeeping Superintendents' Association in particular. Furthermore, it enables scientific men to meet on an unbiased common ground for the purpose of integrating their research activities and harmonizing the future development of the national turf program in all its phases. It is now possible for leaders in the turf field to maintain direct contact with one overall scientific group through membership in the American Society of Agronomy. Thus, for the first time, turf has achieved recognition as an important national entity. Officers and other representatives of turf groups in the U. S., through membership in the A.S.A., may now have a voice in shaping the future of U. S. turf.

"The authority for this action may be found in a file of letters written to Dr. Iver Johnson, Iowa State College, Ames, Iowa, who was then chairman of the Crops Section of the A.S.A. These letters came to him in response to a letter written by Dr. Fred V. Grau, director of the U.S.G.A. Green Section, to scientific men in 20 states. The states selected embrace the major turf areas in the country at the present time. The men who were asked to comment on the proposal included nearly all of those known to be engaged in agronomic research and extension at experiment stations directly or indirectly concerned with turf. The action was supported by the Bureau of Plant Industry, Soils and Agricultural Engineering of the U.S.D.A. with whom the U.S.G.A. Green Section has worked cooperatively for 25 years. The Green Section and the Bureau of Plant Industry, working together, have as their common interest the development and improvement of all phases of turf in the country. It is significant that in this file of correspondence there is not one dissenting opinion on the proposed action which has now been approved.

"The full significance of this step forward remains to be seen. Leaders of the many turf groups throughout the country are invited and urged to take membership in the American Society of Agronomy through the secretary-treasurer, Dr. G. G. Pohlman, Morgantown, West Virginia, and to attend the meetings of the Society which are announced in the official Journal. Correspondence relative to the development of the Turf Section for 1946 should be addressed to Dr. Fred V. Grau, Director, U.S.G.A., Green Section, Plant Industry Station, Beltsville, Maryland, Chairman of the Turf Committee of the Society. The year 1946 will be one of planning and development, preparation for a program of presentation of technical papers on turf at the next annual meeting of the Society, and of securing nationwide participation in the program among all groups interested in turf development. Much can be accomplished through cooperative harmonious action."

The first Turf Committee was composed of H. B. Musser, M. E. Farnham, H. R. Albrecht, and F. V. Grau, Chairman.

In a letter to G. H. Ahlgren in August 1946, Grau made the following statement: "Three main considerations seem to stand out as important in this first meeting within the Society:

(1) Seed production of important turfgrasses.
(2) Weed control in turf.
(3) Turf problems, including technical problems and those of personnel and acceptance of turf as a major agricultural enterprise.

In September 1946, titles and abstracts of papers for the first Turf Management Program were received and approved.

The first Turf meeting held within the Society at Omaha, Nebr., in November 1946 very nearly proved to be the last. The space allotted to the Turf Group was on the Mezzanine, just inside the railing above the hotel lobby. The noise and confusion of the lobby were magnified and intensified to the point where it seemed, at times, folly to continue the meeting.

The fact that those present persisted and did present their papers while those trying to listen kept on trying was something of a miracle. That ordeal having been met and the test passed, plans were made for the second meeting to be held in November 1947 in Cincinnati. H. R. Albrecht was Chairman of Section V, Special Crops in the Crop Science Division. The 1947 Program and Turf Committee Report are a matter of record in the official program and in the *Agronomy Journal*, as are all subsequent programs and reports.

REPORT OF THE 1955 TURFGRASS COMMITTEE

The 1955 Turfgrass Committee was divided into subcommittees for the development of specific information.

Research—Almost all stations engaged in turfgrass work have seen the need for expanding the program on a broad basis in all phases of use. It is understood that a review of turfgrass research is being compiled by the U.S.G.A. with anticipated publication in December 1955.

Teaching and extension—The need for training practical turfgrass superintendents in a 4-year college course is considered acute. At least four universities now offer such a course. Of special interest to the A.S.A. is the increase in numbers of college students registering for Turf Management options, where available, in order to apply the scientific knowledge available in the field of agronomy to the special interest of growing turf for recreational uses.

Grasses—Emerald zoysia for lawns was released in 1955 from the Georgia Coastal Plain Experiment Station. Production and distribution of new strains reported last year (Pennlu, Penncross, Pennlawn, Penngift) have proceeded rapidly.

Reading list—A list of Turfgrass Reference Material for Graduate Students is being completed and will be available upon request from the Chairman of the Turfgrass Committee. An additional list of current articles will be carried in the U.S.G.A.'s review of turfgrass research.

Turfgrass management—Management and techniques can be improved more quickly than new varieties of grasses; therefore, continued emphasis will be placed upon management improvement. Education of supervisory personnel through Turfgrass Conferences plus the increased support by industry of agronomic education has already been very productive in providing more uniformly good turf in the several phases of use. Selective herbicides continue to receive active attention from research. Crabgrass control by means of disodium methyl arsonate is an example of research and industry coordinating their efforts.

Equipment—Turfgrass equipment introduced during 1955 was for the most part improvement or modification of existing equipment.

1. A mechanical power plugger.
2. Adaptation of electrically timed automatic and hydraulically operated sprinkling device for controlled irrigation.
3. Adaptation of injector systems permitting use of herbicides, insecticides, fertilizers, etc. through regular sprinklers.
4. New versions of equipment for breaking up crusted seedbeds and renovating established turf.
5. Seen for the first time last year, the trend toward electric self-starters on large mowing equipment has continued, and during 1955 was introduced on smaller units.
6. Equipment has been developed for deep-rooted pruning of trees adjacent to turfgrass areas.

7. Gasoline powered edgers and combination edge-trimmer units for the home owner and for institutional use.
8. Catchers for small rotary-type lawn mowers.
9. Improved trailers for transporting equipment.

Conferences—During 1955, some 23 educational turfgrass conferences will have been held at various colleges and universities in the United States and Canada. Subject matter is generally divided into two phases: (1) basic principles and (2) practical application of these principles. The second phase is often given on a prescription basis; i.e., do this, at this time, in this manner. An increasing number of conferences are concentrating on a single subject matter theme. This approach provides opportunity to explore basic interrelationships of cultural practices and to study them in relation to practice.

National coordination of conferences has been a subject of discussion for several years. It involves scheduling of local, regional, and national conferences to avoid conflicts. Further, in some areas closer cooperation between various turfgrass interests seems indicated. During the past two years, Regional Directors of the U.S.G.A. Green Section, members of industrial firms, and Experiment Station personnel have been of great assistance in coordinating many of the conferences. However, no completely satisfactory solution for national coordination of conferences has been found. It will be difficult to achieve.

Recommendations—The Committee recommends a continuing study of all phases of turfgrass conferences.

K. Anderson	A. G. Law
W. H. Daniel	H. B. Musser
J. A. DeFrance	O. J. Noer
R. E. Engel	G. C. Nutter
M. H. Ferguson	H. H. Rampton
R. M. Hagan	V. T. Stoutemyer
C. K. Hallowell	M. R. Watson
J. C. Harper	Fred V. Grau, *chairman*

MINUTES OF THE MEETING, AGRONOMIC EDUCATION DIVISION

Aug. 16, 1955

Darrel Metcalfe, vice chairman of the Agronomic Education Division, conducted the 1955 business meeting of the division.

L. G. Monthey, executive secretary of the American Society of Agronomy, gave a report on the agronomy pamphlet, "You Help to Make a Better World Through Your Career in Agronomy" prepared by the Brochure Committee and published and distributed by the American Society of Agronomy.

Reports were given for the three sections of the Agronomic Education Division; N. C. Brady, past chairman for Resident Teaching, H. E. Jones, chairman for Extension, and R. M. Swenson, chairman for Student Activities.

N. C. Brady read the report of the Committee on Training for Agronomists in the absence of D. G. Hanway, chairman of that committee.

The chairman was instructed to appoint a committee of two to work with B. R. Bertramson on the Awards Committee of the American Society of Agronomy on questions concerning student awards. R. C. Potts and A. R. Schmid were appointed.

S. R. Anderson, J. D. Pendleton, and K. J. Patterson, chairman, were appointed to develop resolutions for presentation to the American Society of Agronomy Board. The following resolutions were adopted and presented:

> *Resolved,* That the papers given at the General Meeting of the Agronomic Education Division, Tuesday, Aug. 16, 1955, (See p. 19—1955 Program of the American Society of Agronomy) be repeated on the 1956 General Program of the American Society of Agronomy in lieu of the address usually presented at that time.
>
> *Resolved,* That at each annual convention the meetings of all sections of the Agronomic Education Division be held in the headquarters building of the American Society of Agronomy.
>
> *Resolved,* That the American Society of Agronomy initiate an awards program in the Agronomic Education Division with (1) two awards annually, one in teaching and one in extension; and (2) an award to the outstanding agronomy student in each local Student Activities Section.

H. E. Jones was elected 1956 vice chairman of the Agronomic Education Division.

Darrel S. Metcalfe, *vice chairman*

SUBDIVISION XIII-B, EXTENSION

This sub-section has carried three activities during the past year.

1. The Agronomic Extension annual breakfast program. The breakfast in 1955 was the fifth since formal organization of the sub-section. During 1954 in St. Paul, Minn., 63 agronomists and guests attended the fourth annual breakfast. Forty agronomists attended this year's breakfast. The 1955 group discussed the topic "Responsibilities of an Extension Agronomist."
2. For the second year the sub-section sponsored a half-day's program of papers presented by extension personnel. The sub-section feels that this activity in presenting new developments in the field of applied agronomic teaching is much worthwhile. They desire that it be continued as a part of the Societies meeting program.
3. In 1953 the sub-section appointed a committee on training of agronomists. J. C. Lowery has been committee chairman. The committee continued its activity during the past year. However, because the Agronomic Education Division also set up a committee during the 1954 meetings on this problem, the sub-section disbanded its committee. The sub-section petitioned the Agronomic Education Division for inclusion of an extension member on the committee.
4. Professor C. J. Chapman, Madison, Wis., was elected as 1956 vice-chairman and program chairman for subdivision 13-B.

Harold E. Jones, *chairman*

MINUTES OF THE MEETING, RESIDENT TEACHING SECTION—AGRONOMIC EDUCATION DIVISION—AUG. 17, 1955

N. C. Brady, past chairman of the Resident Teaching Section conducted the business meeting. Don Hill presented the Bylaws as drafted by the Bylaws Committee for the Resident Teaching Section and they were adopted.

J. B. Peterson submitted a resolution relative to awards for resident teachers and extension workers. The following resolution was passed:

> *Resolved,* That an award be established by the American Society of Agronomy, and given each year to an outstanding resident teacher and to an outstanding extension agronomist.

Harold L. Schudel was elected 1956 vice chairman of the section.

J. K. Patterson, *chairman*

RESOLUTIONS AND NECROLOGY

EXPRESSION OF APPRECIATION

The Societies take this means of expressing their appreciation to the staff and the administration of the University of California not only for the facilities that have contributed to the success of our meetings, but also for the many courtesies that have made our stay so pleasant.

It is recommended that the Executive Secretary be requested to send an appropriate letter to Dean Briggs, College of Agriculture, in behalf of the Societies.

Letters are also recommended in appreciation of the fine support given by the following:

The California Seed Association
Pacific Chemical and Fertilizer Co.
The American Factors, Limited
United Airlines
Pineapple Research Institute
California Fertilizer Association.

J. E. Adams, *chairman*

MEMORIALS

Again we pause to pay respect to the memories of those agronomists and soil scientists who have died since we last met. These men made notable contributions to our profession. Their passing will be keenly felt, especially by those who knew them best. These biographical sketches will serve as memorials to these men who have been faithful members of the Societies.

KENNETH M. COOPER

Kenneth M. Cooper, graduate student in soil science in Michigan State University, died July 23, 1955, in a Reed City, Mich., hospital from injuries received in an automobile accident.

Mr. Cooper was born May 15, 1932, at Floyd, N. Mex. In 1954 he received a B.S. degree with honors in chemistry from Eastern New Mexico University. He had completed most of the requirements for the M.S. degree.

His major interest was in soil genesis and classification. At the time of his death, he was employed by the Michigan State Conservation Department in making a cooperative soil survey of Osceola County, Mich.

G. WARREN DEMING

G. Warren Deming, U.S.D.A. geneticist, died June 19, 1955. He was born at Fleming, Ohio, March 31, 1890, and was graduated from the Universty of Nebraska in 1918. He was on the staff of the Colorado Agricultural Experiment Station from 1921 to 1930 working in field crops. In 1931 he was appointed assistant agronomist for the U.S.D.A. in the office of sugar crops and devoted his time until his death to sugar beet investigations. He selected and purified some 300 inbred lines of sugar beets which are the basis of the beet breeding program conducted by the U.S.D.A. and commercial sugar companies. In this field, his work has been outstanding.

CHARLES W. DOMBY

Charles W. Domby, soil scientist in the U.S.D.A. Soil and Water Conservation Research Branch, died at Athens, Ga., on Dec. 21, 1954, after an illness of several months. He was born in Birmingham, Ala., in 1919 and received his B.S.A. degree from Colorado A & M College in 1940. He was employed by the Soil Conservation Service until 1941 when he was inducted into the U. S. Army, serving as an officer in the Corps of Engineers. He obtained his M.S. degree from the University of Georgia in 1948 and his Ph.D. degree in soil physics from Purdue University in 1953. His contributions include articles on diffusion of air through soil crusts and the effect of freezing on soil aggregation. He was highly respected for his keen scientific mind and loved by all who knew him for integrity, modesty, generosity, and tolerance.

CHARLES A. HELM

Charles A. Helm, professor of field crops at the University of Missouri, died of a heart attack on July 24, 1955. He had been named head of the field crops department and would have assumed that position in September of this year. Prof. Helm was born at Sheldon, Mo., in 1889. He received the B.S. degree from the University of Missouri, and the M.S. degree from the University of Nebraska. He returned to the University of Missouri following graduate study and was a member of the field crops department until the time of his death.

W. M. JARDINE

W. M. Jardine, former president, and honorary life-time member of the American Society of Agronomy, and Secretary of Agriculture in the Coolidge administration, 1924–28, died Jan. 17, 1955 in San Antonio, Tex., at the age of 76. Dr. Jardine was president of the Society in 1917. At that time he was director of the Kansas Agricultural Experiment Station. Later he served as president of the college.

CHARLES E. MILLER

Charles E. Miller, Michigan State University soil scientist, died March 27, 1955. He was born June 23, 1885, in Coles County, Ill., and was educated at Kansas State College, the University of Illinois, and the University of Wisconsin, receiving the Ph.D. degree from Wisconsin in 1923. Dr. Miller was elected a Fellow of the American Society of Agronomy in 1936, and served the Society in many ways. His books, *Soils* and *Soil Management*, and *Fundamentals of Soil Science*, are well known to workers in Agronomy throughout the world. He first became associated with Michigan State University in 1915, and progressed steadily to become head of the soil science department in 1930.

FREDERICK J. SALTER

Frederick J. Salter, associate professor of agronomy in teaching and extension at Ohio State University from 1940 until his retirement in 1953, died of a heart ailment Feb. 9, 1955, after a short illness.

He was born in Lacrosse, Kans., Sept. 28, 1889. He received a B.S. degree from Ohio State University in 1913, an M.S. degree in 1914, and the Ph.D. degree in 1929. Dr. Salter was an instructor in agricultural chemistry at Ohio State University from 1913 to 1919, and in soils from 1924 to 1927. He was assistant professor of extension in 1925, and assistant professor of agronomy in 1929.

Dr. Salter was outstandingly successful as a teacher from elementary classes to graduate students. He is beloved of many generations of Ohio State students, and will be long remembered by them for this deep personal interest in their problems, and for consultation and guidance during their academic careers.

HI W. STATEN

Hi W. Staten, professor of agronomy at Oklahoma A & M College, died July 5, 1955, following a brain operation. He was 59 years of age.

Mr. Staten was born at Pikeville, Ky., in 1895. He held the B.S. and M.S. degrees from Oklahoma A & M College where he was appointed assistant professor of agronomy in 1930. He left the college in 1936 to become senior agronomist for the Soil Conservation Service in Oklahoma, Kansas, and Nebraska, but returned in 1937 and was appointed professor of agronomy in 1941.

Except for the war years, 1942–46, and the year spent with S.C.S., Mr. Staten coached the Oklahoma A & M crops judging teams from 1932 to 1948. Since 1948, he had devoted full time to teaching at the college, except for two years on leave in Ethiopia, 1952–54, where he helped establish a college of agriculture and mechanical arts.

Mr. Staten was author of a book on grassland farming and co-author of a manual for crop judges.

J. KEITH THORNTON

Joseph Keith Thornton, superintendent of the department of farm operations and service at Pennsylvania State University since 1948, died March 11, 1955. He was born May 7, 1905, in McKeesport, Pa.

Mr. Thornton, who conducted extensive research on grasses, was graduated from Pennsylvania State in 1927 and received his master's degree from the University of Wisconsin in 1947.

Mr. Thornton came to Pennsylvania State University in 1935 as instructor in farm crops after serving for 8 years as assistant plant pathologist in the U.S.D.A. Bureau of Plant Industry and the Pennsylvania Department of Agriculture. He was promoted to assistant professor at Penn State in 1941, to associate professor of farm crops in 1944, and to the post of superintendent of farm operations in 1948.

Book Reviews

POTASSIUM SYMPOSIUM—1954

Compiled by the International Potash Institute—Bern, Switzerland. 445 pages.

This book contains 21 papers given at the annual meeting of the Board of Technical Advisors of the International Potash Institute at Zurich. The meeting was divided into four sessions: potassium in the soil; potassium in the organisms; potassium in agriculture; and potassium analysis. Papers were presented by many of the leading agronomists from several countries of Europe. While the papers are in French, German or English, all have an English summary. The purpose of the papers was to outline the position of our present knowledge—chemical, physiological, and agricultural—in respect to potassium. Hence they covered a wide field and reviewed a number of basic principles.

In the session on potassium in the soil, papers dealt with physico-chemical properties, geochemistry, clay minerals releasing potassium, and forms of potassium. Several subjects were covered in the session on potassium in living organisms including demands of microorganisms, accumulation, functions in animals, and function in plants.

In the program on potassium in agriculture, the great need for potassium was stressed. Considerable increase in potassium usage has taken place in recent years and in Belgium and Denmark about 60 kg. of K_2O per hectare is being applied. Soil tests and field

trials have contributed greatly to these increases. The use of potassium fertilizers in Switzerland is comparatively low as farmyard manure supplies about 90% of the need.

Flame photometry and chromatographic methods of analysis were among the subjects covered in the session on analysis. K. A. Bondorff discussed a flame photometer constructed in his laboratory for routine analyses. V. Morani indicated the possibilities of successive extractions in differentiating between soils with a low reserve of potassium and those with a high reserve. T. Walsh brought out some excellent points on the possibilities and limitations of deficiency symptoms and plant analyses in diagnosing potassium needs. The International Potash Institute is to be commended for bringing together this group of scientists for these objective discussions.—WERNER L. NELSON

COTTON GROWING PROBLEMS

By B. G. Christidis and G. J. Harrison. New York. McGraw–Hill Book Co. 1955. $9.75.

This book, written by B. G. Christidis of Greece and co-authored by G. J. Harrison of this country, is a well organized treatment of present day problems that confront cotton workers.

The book has 21 chapters and includes a discussion of cotton varieties, cotton breeding, crop rotation, soil cultivation, fertilization, the cotton seed, planting, cultural methods, insect pests, diseases, and harvesting. A modern treatment of additional subjects such as insecticides, chemical weed control, mechanical harvesting, irrigation practices, and chemical defoliation greatly enhance the value of the book. This book does not, however, include such subject matter as ginning, marketing, and cotton morphology, an adequate treatment of which would have made the book more valuable for classroom use.

In general, the subject matter is up-to-date, including some data which are published for the first time. The text is unique, but at times leans rather heavily toward experiments conducted in Greece. However, the subject matter is by no means localized. The bibliography is extensive and gives a broad coverage of the world literature on cotton. References given are sufficient for a more detailed study of cotton growing problems.

The majority of the text is readily understandable to the non-specialist, and as a result, this book is recommended to both the grower and scientist alike.—L. C. BROWN.

WATER

The Year Book of Agriculture 1955

U. S. Department of Agriculture. Government Printing Office. 751 pp. 1955. $2.00.

The 1955 year book of the U.S.D.A. is devoted to all aspects of the subject of water. It contains 95 chapters written in non-technical style by 149 specialists in U.S.D.A., the state agricultural colleges and experiment stations, and other private and federal agencies. Among the subjects covered are: the importance of water in history; the need for water of people, animals, and plants; weather cycles, "cloud seeding"; desalting sea water; water and erosion; care of watersheds; waters laws; flood control; water for forest and range lands; irrigation; drainage, watershed maintenance for better fishing; wetlands and water fowl; dry land farming; use of waste water by industries; water for gardens and lawns; rural drinking water supplies; sewage disposal; conservation, and research. It contains many excellent illustrations and useful charts and graphs. Many members of the American Society of Agronomy and Soil Science Society of America are among the contributors. Copies are available through members of Congress or from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at $2.00 each.

INTRODUCTION TO AGRICULTURAL ENGINEERING

By H. F. McColly and J. W. Martin. New York, McGraw–Hill Book Co. 553 pp. illus. 1955. $7.50.

This new book, written for agricultural students and farm advisers, is conveniently divided into eight parts: (1) engineering in agriculture; (2) agricultural mechanics; (3) farm power; (4) farm machinery; (5) rural electrification; (6) processing agricultural products; (7) farm structures and conveniences; and (8) soil and water conservation engineering. The principles and the practical aspects of these various types of farm engineering are treated comprehensively. The latest developments in equipment used in production, handling, and processing of farm crops are discussed. The volume will be particularly valuable as a reference for those with a broad interest in this general field.

PRINCIPLES OF FARM MACHINERY

By Roy Bainer, R. A. Kepner, and E. L. Barger. New York, John Wiley & Sons, Inc. 571 pp. illus. 1955. $8.75.

Principles of Farm Machinery is intended as a textbook for an upper-division college course in farm machinery. The book covers machinery according to the uses to which the machines are put. For example, typical chapter headings include: moldboard-type tools, disk tools, application of fertilizer, crop planting, forage chopping and handling, earth-moving equipment, and farm transport. Introductory chapters cover such topics as field capacities and cost analysis, materials of construction, and hydraulic controls and power-take-off drives. An extensive appendix treats many miscellaneous aspects of farm machinery and its use.

TOPSOIL AND CIVILIZATION

By Tom Dale and Vernon Gill Carter. Norman, Okla., The University of Oklahoma Press. 270 pp. 1955. $3.95.

It is generally agreed that exploitation and depletion of natural resources are significant contributing factors to the rise and fall of civilizations throughout world history. Just how these factors came about and the extent of their development are not generally appreciated. In this book the authors attempt to analyze the entire field of world history from the point of view of man's relation to productive soil. It is in the nature of a review, being based largely upon secondary sources. This in no way minimizes the importance of the author's message. They use their survey as a graphic reminder that "The wealth and power of this great nation will decline, as they have in all past empires and civilizations, if and when these (natural) resources are depleted to the extent that they can on longer supply our needs." They examine the ancient civilizations—Egypt, Mesopotamia, Crete and Lebanon, Syria and Palestine, Greece, North Africa, Italy and Sicily, and the modern history of Western Europe and the United States. Less attention is given to Asia and the Orient. The authors recognize that historians and others might take exception to some of their interpretations. This, too, need not detract from the value of this book as a readable history, and its point of view is one which can be readily appreciated in an era of profligate prosperity in some parts of the world and hunger in others. Mr. Dale is with the U. S. Conservation Service, and Mr. Carter is director of conservation education in the Zanesville, Ohio, public schools. They have dedicated their book to David A. Aylward and Hugh H. Bennett.

CLASSICS IN BIOLOGY

By August Pi Suner (Translated by Charles M. Stern). New York, The Philosophical Library. 337 pp. 1955. $7.50.

Biologists of all levels of accomplishment will welcome this volume as a "gem". The author is founder of the Institute of Experimental Medicine of Caracas (Venezuela) University, and one of the world's distinguished physicians and biologists. He has compiled extracts from outstanding works of more than 60 writers. Each selection represents a high point of progress in the study of biology. Dr. Suner's prefatory essays themselves are of extremely high merit. The selections are grouped under the following headings: matter and energy in life, cell theory; stimulus and excitation; biocatalysts; metabolism; growth and reproduction; germ cells and soma: sexual and asexual reproduction; form and dynamics of reproduction; heredity; individual and species, preformation and epigenesis, life on earth; geography and palaeontology, causation and design; reflexes, consciousness and will; and the whole and its parts.

A partial list of the authors included in the selections includes: Aristotle, Plato, Lavoisier, von Koelliker, Borelli, von Liebig, F. G. Hopkins, Gautier, Strasburger, J. S. Huxley, C. B. Bridges, Mendel, Linnaeus, E. B. Wilson, von Humboldt, St. Augustine, Scheler, Freud, Descartes, Ramon y Cajal, Bergson, Haldane, and Ortega y Gasset.

Agronomic Affairs

MEETINGS

Jan. 4–5—Weed Society of America, charter meeting, New York, N. Y.
Jan. 6—Northeastern Weed Control Conference, New York, N. Y.
Jan. 12–14—Conference on radioactive isotopes in agriculture, Michigan State University.
Jan. 23–27—American Society of Range Management, Denver, Colo.
Jan. 26–28—American Seed Trade Association, Chicago, Ill.
Feb. 3—Canadian Seed Trade Association, Toronto, Canada.
Feb. 6–8—Southern Branch, American Society of Agronomy, and Association of Southern Agricultural Workers, Atlanta, Ga.
Feb. 15–17—Western Weed Control Conference, Sacramento, Calif.
March 5–7—Midwest Regional Turf Conference, Lafayette, Ind.
March 6–7—Western Cotton Production Conference, Fresno, Calif.
March 18–24—Consecutive Meetings, American Congress on Surveying and Mapping, and American Society of Photogrammetry, Washington, D. C.

INTERNATIONAL CROP GROUP HONORS THREE AGRONOMISTS WITH LIFE MEMBERSHIPS

Three long-time members of the International Crop Improvement Association were given honorary life memberships at the group's annual meeting Nov. 8–11 at Winter Haven, Fla. They are W. T. G. WIENER, Canadian Seed Growers Association, Ottawa; J. C. HACKLEMAN, University of Illinois; and L. F. GRABER, University of Wisconsin.

Close to 250 certification officials, breeders, seedsmen, and others from 40 states, Alaska, and Canada attended the meeting.

R. H. GARRISON, South Carolina Crop Improvement Association, Clemson, is new president of the association, succeeding C. R. PORTER, University of Nebraska. Other officers for 1955–56 are H. E. FINNELL, Oregon State College, vice president; and C. S. GARRISON, U.S.D.A., Beltsville, Md., secretary. The 1956 meeting will be at Salt Lake City, Utah.

CHARTER MEETING OF WEED SOCIETY JAN. 4–5

Weed authorities from three nations will gather at the Hotel New Yorker in New York City Jan. 4 and 5 for the charter meeting of the Weed Society of America. The theme of the meeting will be "Modern Weed Control—A New Science," according to A. O. KUHN, University of Maryland, program chairman.

Officers of the new society are R. H. BEATTY, American Chemical Paint Co., Ambler, Pa., president; W. B. ENNIS, Jr., State College, Miss., vice president; and W. C. SHAW, U.S.D.A., Beltsville, Md., secretary-treasurer.

The Northeastern Weed Control Conference, host to the Weed Society meeting, will have a program and business session on Jan. 6.

A general session, business meeting, and mixer are scheduled for Jan. 4. W. B. ENNIS and R. H. BEATTY are chairmen of morning and afternoon sessions. Sectional meetings to be held on Jan. 5 and their chairmen are as follows:

1, agronomic crops, C. J. WILLARD, Ohio State University; 2, horticultural crops, R. D. SWEET, Cornell University; 3, noncultivated areas, R. A. DARROW, Texas A & M College; 4, ecological, physiological, and edaphic aspects of weed control, A. S. CRAFTS, University of California, Davis; 5, turf, G. C. NUTTER, University of Florida, Gainesville; 6, public health, A. H. FLETCHER, New Jersey State Department of Health; 7, W. S. BALL, California State Department of Agriculture; 7, teaching and extension, E. P. SYLWESTER, Iowa State College; section 9, control of aquatic weeds, F. L. TIMMONS, University of Wyoming.

SUMMARY OF RESEARCH ON WOOD RESIDUES FOR SOIL IMPROVEMENT AVAILABLE FROM PURDUE STATION

A report covering the current status of investigations on the use of wood residues for soil improvement in the U. S. has been compiled by a work group of the North Central Regional Soil Research Committee, and copies are available from the work group upon request, says H. W. REUSZER of Purdue University.

The report contains an abbreviated summary of research work now being carried out in this country on the use of sawdust and wood chips for soil improvement. Present knowledge is summarized briefly and suggestions are made as to questions on which further knowledge is needed. Information in the report, it is thought by the group, will aid in preventing duplication in future research work. The North Central Regional Soil Research Committee represents soil research workers in the North Central States.

Members of the work group, in addition to Reuszer, are R. L. COOK, Michigan State University, and E. R. GRAHAM, University of Missouri. Requests for copies should be sent to Dr. Reuszer, % Department of Agronomy, Purdue University, Lafayette, Ind.

HENRY M. STEECE DIES IN WASHINGTON, D. C.

HENRY M. STEECE, 63, Agricultural Research Coordinator, State Experiment Stations Division, A.R.S., U.S.D.A., died on Nov. 21 at his home in Washington, D. C., following a brief illness. A national authority on field crops production and plant genetics Mr. Steece was widely known among agronomists of the state experiment stations and land-grant colleges. He first entered the U.S.D.A. service in 1914 in corn and cotton investigations in the former Bureau of Plant Industry. In 1920, following military service including 13 months in France during World War I, he joined the staff of the Office of Experiment Stations.

Born in Burlington, Iowa, on July 1, 1892, Mr. Steece obtained his B.S. in agronomy at Louisiana State University in 1913 and an A.M. degree at George Washington University in 1922. He was a member of the American Society of Agronomy and of the U.S.D.A. Post No. 36 of the American Legion. He is survived by his widow, Edith W. Steece, and 5 children and 10 grandchildren. Services were held Nov. 25 with interment at Arlington Cemetery.

BY-LAWS OF THE RESIDENT TEACHING SECTION OF THE DIVISION OF AGRONOMIC EDUCATION

Article I, Name

The name of this Section shall be the Resident Teaching Section.

Article II, Objectives

The objectives of this Section shall be those of the Division of Agronomic Education: to promote the training of Agronomists (crop and soil scientist) on both the under-graduate and graduate level, but especially the fostering of high standards in resident teaching, and to encourage student activities in the field of Agronomy.

Article III, Membership

Section 1.—Active members of this Section shall be members of the American Society of Agronomy who are interested in fostering high standards in resident teaching.

Section 2.—Student affiliate members of the Society are student affiliate members of this Section. They shall be encouraged to attend and participate in the meetings of the Section, but will not have the privilege of voting.

Article IV, Officers

Section 1.—The officers of this Section shall consist of a chairman, vice-chairman, who shall be chairman-elect, and immediate past chairman. All officers shall be active members of the American Society of Agronomy.

Section 2.—The vice-chairman shall be elected by secret ballot at the annual business meeting of the Section. Previous to this business meeting the chairman of the Section shall appoint a nominating committee consisting usually of three past chairmen of the Section who shall submit two or more nominees for consideration. Additional nominations may be made from the floor at the time of election. The nominee receiving the largest number of votes shall be declared elected. In case of a tie vote the chairman shall cast the deciding vote.

Section 3.—All officers of the Section shall serve in the office to which they were elected until the close of the next annual

business meeting of the Section. At that time their respective terms of office shall expire. The vice-chairman shall automatically become chairman at the close of the business meeting at which a new vice-chairman is elected.

Section 4.—The duties of the chairman and vice-chairman shall be those which usually pertain to the offices held. The vice-chairman shall serve as program chairman and as secretary of the Section. The officers of the Resident Teaching Section will coordinate and plan their programs in conjunction with the officers of the Division of Agronomic Education.

Section 5.—The Executive Committee of the Section shall be the chairman, vice-chairman, and immediate past chairman. The executive committee shall have power to act for the Section upon all matters that arise between business meetings of the Section.

Section 6.—If a vacancy should occur in the offices of the Section, a successor will be appointed by the Executive Committee of the Division of Agronomic Education. Such an officer shall serve until a successor is elected at the next annual business meeting of the Section.

Article V, Meetings

Section 1.—The Section shall present one or more programs at each annual meeting of the Society. The business meeting shall be held at one of these meetings.

Section 2.—Joint programs with other Sections or Divisions of the Society on subjects of mutual interest will be encouraged by the Executive Committee of the Section.

Article VI

Section 1.—Any 20 or more members of the Resident Teaching Section may initiate a proposed amendment to these by-laws. The amendment shall be submitted to the membership with recommendations either at the next annual meeting or by mail ballot.

Section 2.—The Executive Committee may propose amendments to those by-laws at any time either by mail ballot or at the annual meeting.

Section 3.—The Executive Committee shall submit the proposed amendments to the membership at least 60 days before they are voted on. Adoption of a proposed amendment shall require a majority vote of those present at an annual meeting of the Section or, if by mail ballot, a majority of all ballots returned within 60 days after the date of the original mailing.

NEWS NOTES

Russell K. Stivers joined the Purdue University agronomy department on Nov. 7 to work in soil fertility and tobacco extension. He had spent the previous 5½ years at the Virginia Agricultural Experiment Station, Blacksburg.

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Lyle E. Nelson of the Cornell University agronomy department is now visiting professor of soils at the Cornell–University of the Philippines College of Agriculture. On a 2-year leave, he replaces Marlin Cline who has become project leader.

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Loyd A. Tatum was recently named assistant head of the Cereal Crops Section of the Field Crops Research Branch, A.R.S., U.S.D.A., at Beltsville, Md. He was formerly agronomist in charge of the section's cooperative corn project at the Kansas agricultural experiment station, Manhattan.

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H. H. Smith is on leave from the Cornell University department of plant breeding until Oct. 1, 1956 with the Brookhaven National Laboratory, Upton, L. I., N. Y. During his absence, special lectures and student consultations will be offered by the following visiting professors: for the spring 1956 semester, A. H. Sparrow, Brookhaven National Laboratory, who will give a course in radiobiology; for the month of December 1955, M. Westergaard, head of the department of genetics, Copenhagen University; for June 1956, M. M. Rhoades, professor of botany, University of Illinois; for July, 1956, S. G. Stephens, head of the genetics faculty, North Carolina State College; for August 1956, R. D. Owen, professor of biology, California Institute of Technology.

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R. L. Beacher, associate agronomist in charge of the soil testing and research laboratory at the University of Arkansas, presented a paper on sampling and analysis of rice soils at the annual meeting of the F.A.O. International Rice Commission in Malaya early this month.

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Isidoro A. Romero has resumed his duties as soil technologist of the Bureau of Soil Conservation, Philippine Department of Agriculture and Natural Resources, Manila. He had spent 10 months in the U. S., Puerto Rico, London, Munich, and Rome under a U. S.–Philippines training grant on soil classification. Illuminado Valencia, who recently received the M.S. degree from the University of Wisconsin, is now soil physicist in the Bureau of Soil Conservation. He is also on the faculty of the Philippine Women's University physics department. Ramon Samaniego, who recently received his M.S. degree from North Carolina State College, has resumed his duties as soil physicist in the Bureau of Soil Conservation.

PERSONNEL SERVICE

Insertions accepted without charge from members of the American Society of Agronomy. For others, the charge is $2.00. Soils items will be inserted also in Soil Science Society of America Proceedings. Insertions are for 1-time only. Please limit to 100 words.

POSITIONS WANTED

Soil Chemist, Ph.D., interested in suitable research or teaching and research position of permanent or prospectively permanent nature. Specialist in physical chemistry of clay minerals and soils. Presently engaged on temporary research project in clay mineralogy. Experience includes fundamental research in ionic exchange and phosphate fixation as well as investigations in soil fertility, soil moisture, and irrigation problems. Basic training in soil science, plant science, and chemistry. Well acquainted with chemical and physical methods, field plot technique, experimental design and statistical analysis. Obtained bachelor's degree in 1942. Citizen of Canada, now resident of U. S. Age 36. Family. 12–1

—A—

B.S., M.S. in agriculture with 8 years experience in commercial research involving use of radioactive materials wishes position where this experience can be more directly applied to agriculture. Also had experience in employee relations and supervision. Would be interested in a position involving coordinating atomic research or management. Presently employed, but available on usual notice. 12–2

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Agronomist M.S. in Soils (1952) Ph.D. in Farm Crops (1955)-Crop production-Forage crop establishment-Range Management, with minors in Agr. Education, Agr. Economics, 48 yrs. old, married without children, free of prejudice for race, nationality, or color, desires position in teaching, research, experimentation in Agr. College, Private Company, Non-profit Institution here or abroad. 12–3

POSITIONS OPEN

Soil chemist needed, with excellent physical chemistry training, in inter-college exchange program with the Punjab University, Lahore, Pakistan. Two-year assignment, 20% post differential, cost of living allowance, first class travel by air, and housing. Write B. R. Bertramson, chairman, Department of Agronomy, Washington State College, Pullman, Wash.

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